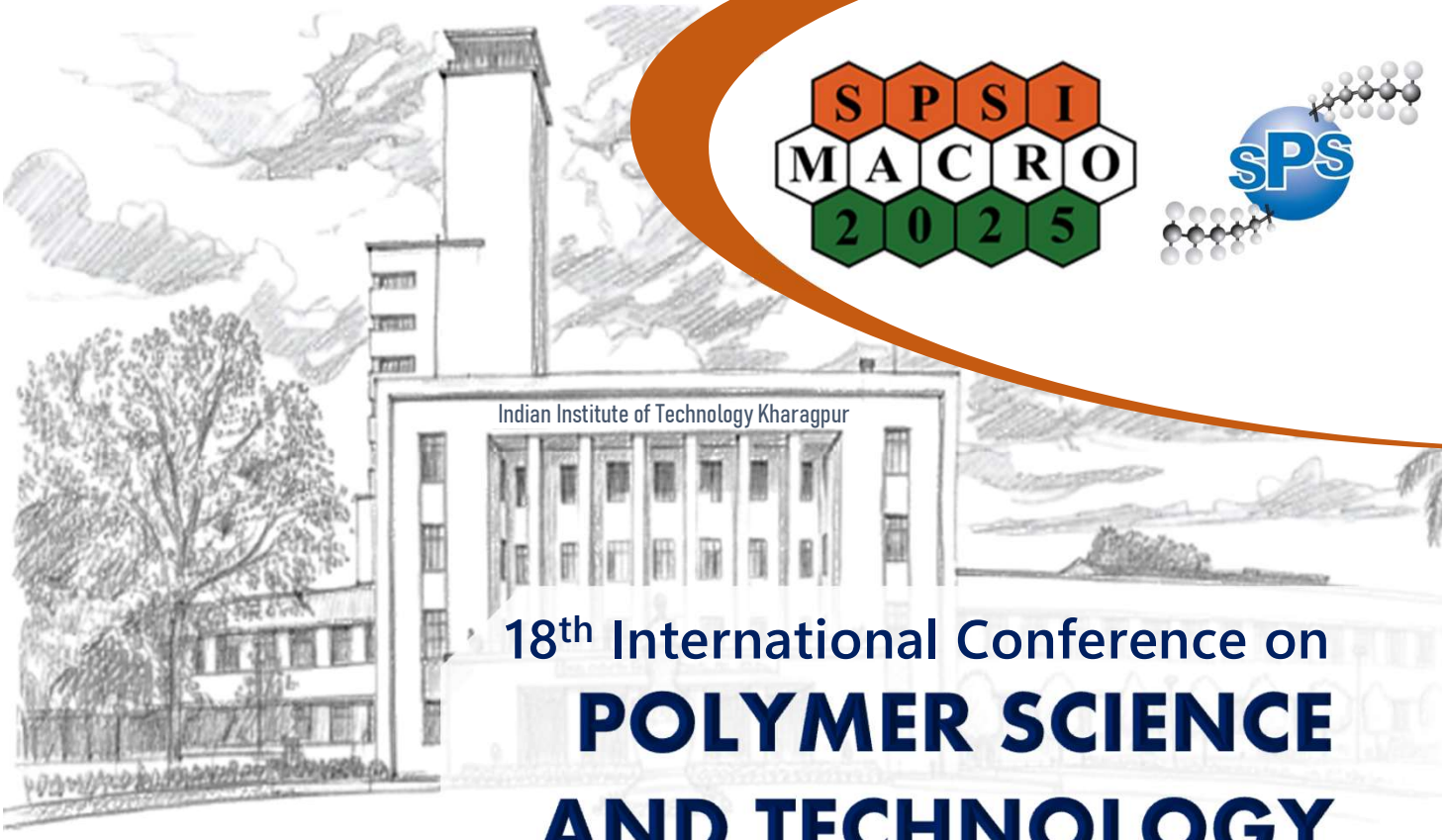


SPSI MACRO 2025

SPS

18th International Conference on POLYMER SCIENCE AND TECHNOLOGY

DEC 15-18

SPSI MACRO 2025

BOOK OF ABSTRACTS

Organized by

Indian Institute of Technology Kharagpur &
The Society of Polymer Science India (SPSI)

75 राष्ट्र सेवार्थ समर्पित 1951 DEDICATED TO THE SERVICE OF THE NATION

18th International Conference on

POLYMER SCIENCE AND TECHNOLOGY

(SPSI MACRO 2025)

December 15-18, 2025

Organized by
Indian Institute of Technology (IIT) Kharagpur, India
& The Society for Polymer Science India (SPSI)

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PREFACE

On behalf of the organizing committee of the **SPSI-MACRO-2025**, we are delighted to welcome you to the IIT Kharagpur Research Park, Kolkata, for the four-day "**International Conference on *Polymer Science and Technology"***, organized as a part of the Platinum Jubilee celebration of IIT Kharagpur. This conference marks another milestone in the journey of the Society for Polymer Science, India (SPSI), which began its modest inception at the Department of Polymer Science, Anna University, Madras, in 1979. Today, SPSI stands as a premier professional organization dedicated to advancing polymer science and technology in India, headquartered at the National Chemical Laboratory (NCL), Pune, and proudly affiliated with the International Union of Pure and Applied Chemistry (IUPAC). Through its commitment to fostering global collaborations and bridging academia with industry, SPSI continues to strengthen research and innovation toward sustainable polymer solutions addressing critical challenges in healthcare, energy, environment, and other emerging sectors. Among SPSI's major initiatives, *SPSI-MACRO* stands as a premier flagship international conference, held biennially and attracting eminent polymer scientists and technologists around the world.

The 18th International Conference in this distinguished series, SPSI-MACRO-2025, is jointly hosted by the Rubber Technology Centre, Department of Chemistry, and Materials Science Centre of our Institute from December 15 to 18, 2025. In the quest for advancement of polymers and elastomer composites, the development of a new class of functional materials and its self-healable, sustainable composites, vitrimers, is the theme of recent research in materials science and engineering. In recent years, artificial intelligence (AI) and machine learning (ML) have been used in the science and technology of polymers and elastomers to develop new materials of desired properties with a well-defined timeline. The goal of the conference is to bring together scientists from academia and industry on a single platform to discuss developments and share recent innovations in the field of functional polymers and their composites. The conference will include lectures on polymeric materials such as vitrimers, high-performance plastic recyclability, biomimetic materials, mechano-adaptive polymers, and speciality polymer and elastomer composites with multifunctional applications, including automotive, energy, healthcare, paint, and coating applications, along with an overview of advanced characterization techniques for functional polymers and their composites and utilisation of AI/ML in polymers.

The SPSI-MACRO 2025 program features nearly 200 talks, along with two endowment lectures, five award lectures, and three plenary lectures delivered by leading experts. More than 300 posters covering diverse research themes are being presented. Different technical sessions will be chaired by leading experts in their fields. With an expected participation of approximately 600 delegates from about 20 different countries, this conference promises a vibrant and intellectually stimulating atmosphere.

We extend our sincere gratitude to all invited speakers, oral and poster presenters, for their enthusiasm and high-quality scientific contributions. Our heartfelt thanks also go to the sponsors, supporters, and advertisers whose generous support has made this event possible. We deeply appreciate the guidance and involvement of the various advisory committees, the Chairmen, as well as the dedication and hard work of our organizing team. We are also grateful to our Director, the Institute Administration, including the offices of Dean Admin, Dean OR, International Relations and Registrar's office. We also acknowledge the invaluable support the invaluable supports from our colleagues, research scholars, and technical staff.

Conveners
Prof. Nikhil K. Singha
Prof. Dibakar Dhara
Prof. Bhanu B. Khatua

Director's Message

ভারতীয় প্রযুক্তিবিদ্যা প্রতিষ্ঠান খড়গপুর
भारतीय प्रौद्योगिकी संस्थान खड़गपुर
Indian Institute of Technology Kharagpur
খড়গপুর/खड़गपुर/Kharagpur 721302

IIT Kharagpur
PLATINUM JUBILEE

অধ্যাপক সুমন চক্রবর্তী, অধিকর্তা
प्राध्यापक सुमन चक्रवर्ती, निदेशक
Professor Suman Chakraborty, Director
Institute Chair Professor & Sir J. C. Bose National Fellow



Director's Message

I am delighted to learn that our Institute is organizing the 18th International Conference on Polymer Science and Technology (SPSI-MACRO) at the IIT Kharagpur Research Park, New Town, Kolkata, from December 15th to 18th, 2025, in association with the Society of Polymer Science, India (SPSI). I understood that this SPSI-MACRO-2025 is jointly organized by the Rubber Technology Centre, the Department of Chemistry, and the Materials Science Center, along with other departments and schools of our institute. As it proudly celebrates its **Platinum Jubilee** milestone, IIT Kharagpur can boast of a remarkable contribution to India's scientific and technological growth through pioneering research, innovations and industrial collaborations. IIT Kharagpur has been spearheading education and research in polymer science and engineering, and rubber technology in our country since 1955. It is a fast-growing interdisciplinary area, and IIT Kharagpur has been a pioneer in developing manpower in the field of Polymer Science and Rubber Technology since then. IIT Kharagpur, with the help of these departments and centers, is producing trained technical manpower to take leading roles in academia and industry. This conference is aimed at bringing together the polymer chemists and the polymer and rubber technologists on a common platform in order to exchange ideas and converge on some innovative and focused areas of research. I understand that there are about 600 participants from 20 different countries of the world, comprising industries, R&D organizations, and academic institutions. I am confident that the delegates participating in the Conference will make significant contributions to the development of science and technology. Besides, the deliberations by peers in the field will inspire budding scientists to explore new directions for further research, ultimately leading to the sustainable development of polymer science and technology.

I understand that the organizers have arranged a very stimulating, interesting and interactive program spanning over four days and it is indeed my privilege to welcome all the delegates of the conference on behalf of this premier institute, the oldest and largest amongst the IITs in the country. Please make the best use of the time to develop a close and lasting link between your organization and our Institute.

I congratulate the organizers and wish them a grand success in their endeavor.

Suman Chakraborty

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Chief Guest's Message

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Bereich Mathematik und Naturwissenschaften
Fakultät Chemie und Lebensmittelchemie
Lehrstuhl für Organische Chemie der Polymere
Prof. Dr. Brigitte Voit



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Dear honourable guests and speakers, dear delegates,
Dear conveners of SPSI Macro 2025,

it is my great pleasure to present a short message in honour of the 18th International Conference on Polymer Science and Technology. The conference, which encompasses all modern topics in polymer science, from synthesis and physics to theory, advanced characterisation, and processing, and most importantly, future-oriented application fields and aspects of sustainability, can already be called a great success. More than 600 delegates from 20 different countries are participating, a clear sign of a highly attractive program. It also emphasises the fact that our modern society, future, and sustainable technologies rely heavily on advances in polymeric materials.

The conference is organized by the Society for Polymer Science India, SPSI, which has been acting for more than 30 years as a nation-wide society to promote the general advancement of Science and Technology of Polymers in India, and to provide a forum for exchange of information amongst the members and persons attached to the Society. I understand that this SPSI-MACRO-2025 Conference is organized by the Rubber Technology Centre, the Materials Science Centre, Department of Chemistry as a part of the Platinum Jubilee of IIT Kharagpur.

Being part of the 75th anniversary of the foundation of IIT Kharagpur is also a very personal matter for me. I have active research collaborations with the IIT Kharagpur for nearly 25 years. My institution, the Leibniz Institute of Polymer Research Dresden, Germany, has the longest and most profitable international academic cooperation with IIT Kharagpur, with multiple student exchanges, mutual visits of PhD students, postdocs, and professors, funded by AvH, DAAD, DFG, INSA, DST, and more than 100 joint publications. Several IPF delegates join this conference, and all of us are very happy to meet friends and colleagues and to celebrate jointly the success story of IIT Kharagpur. But I am especially looking forward to listening to the newest research results, meeting new colleagues, discussing potential collaboration and interacting with the next generation during the conference.

I wish the SPSI-MACRO-2025 a great success and all of you a very enjoyable and profitable conference.

Prof. Dr. Brigitte Voit, Leibniz Institute of Polymer Research Dresden, Germany
December 2025

Guest of Honour's Message

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH
(An Autonomous Institution, Ministry of Human Resource Development, Govt. of India)
Dr Homi Bhabha Road Pune 411008

Professor S. Sivaram, FNA
Honorary Professor, Indian Institute of Science Education and Research, Pune and Kolkata and Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore
December 10, 2025



Message

I am happy to note that the Indian Institute of Technology, Kharagpur is organising the 18th International Conference on Polymer Science and Technology from December 15-18, 2025, at Kolkata under the auspices of the Society of Polymer Science, India (SPSI-MACRO-2025). As someone who nurtured this Society in its formative years, it is indeed gratifying to see that the polymer science community has grown by leaps and bounds in thirty-five years. I had the privilege of organizing the First Conference in Pune in 1991 and it is rare privilege for me to see one of my students, Professor Nikhil Singha, organizing the 18th Conference in this series. It is also worth mentioning that this Conference is being organized in the Platinum Jubilee year of IIT-Kharagpur. IIT-Kharagpur was the first IIT to be set up by a newly independent nation on 18 August 195, a symbol of aspiration of independent India to scale great heights in science and technology. IITs have attained an iconic status and are globally respected for the quality of the students and faculty research. It is, therefore, fitting that this Conference is being held in this historic anniversary year and allows us to reflect on India's strength in polymer science and technology across numerous institutions of higher learning and research.

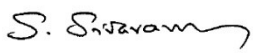
SPSI-MACRO-2025 brings together experts from academia, industry, and research institutions to deliberate on contemporary research in cutting-edge polymer materials and technologies. It is heartening to see a large number of distinguished practitioners of this science from different parts of the world participating in this Conference.

The Conference is both timely and relevant. The rising wave of this young science that began about seventy-five years ago has attained maturity. The growth of commodity life cycle of the polymers has ended with mature manufacturing technologies serving many end sectors of our economy. In the last two decades, polymers have become more invisible in its application compared to the first fifty years of development. Functions have become more important than mere structures. Hence, polymer science research must become more purpose-driven rather than merely driven by curiosity. We need to define useful functionalities of polymers for specific end-applications and apply our innovative capabilities to achieve them in an efficient and economical way. All such solutions, must adhere to the principles of circular economy as well as sustainable chemistry and engineering. Research must focus on what "needs to be done" rather than "what

can be done. It must address the complexity inherent in such problems and solutions. Every potential solution must be examined through the prism of "sustainability science" to ensure that it does not lead to resource depletion, ecological degradation, and transgression of local, regional, and planetary boundaries.

I hope that this Conference will set aside time to deliberate on a few of these emerging challenges and frame the responses of the scientific community to them. The research community must understand how to factor in holistic sustainability considerations in the design and development of advanced materials, so that we may not commit the same mistakes that the earlier generation did, the heavy price of which we are paying today.

I wish the Conference a grand success.



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Presidential Message

THE SOCIETY FOR POLYMER SCIENCE (INDIA)



www.spsi.co.in

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Immediate Past President
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Registered Charity Number:
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It is my pleasure to welcome you all, on my personal behalf and on behalf of the Society for Polymer Science India (SPSI), for the 18th International Conference on "Polymer Science and Technology" (SPSI-MACRO 2025). This is being organized by the IIT Kharagpur team of the SPSI under the leadership of Prof. Nikhil K. Singha. I congratulate Prof. Singha and the organizing committee for hosting this important activity. In fact, this is being held as part of the Platinum Jubilee celebrations of IIT Kharagpur. It is a memorable year for IIT Kharagpur for completing seventy-five years of academic excellence.

SPSI was established in 1979 and has since played an essential role in general advancement of Science and Technology of Polymers in the country by providing a forum for the exchange of information amongst the members and persons attached to the Society. At present, SPSI has ten active chapters to help achieve the stated objectives of the Society.

The organizing committee of SPSI-MACRO 2025 has done excellent work in bringing together so many of the best practitioners of polymer research at one place. This will provide an excellent opportunity for all the young researchers to interact and learn from the best in the field.

I am confident that SPSI-MACRO 2025 will be an excellent event to boost further growth of polymer research and education in India. I am sure all the participants will make the best use of their time interacting and discussing with others to develop new ideas and directions in polymer research.

I wish the SPSI-MACRO 2025 a huge success.

With warm regards

Anil Kumar
(President, SPSI)

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Technical Session Schedule of SPSI MACRO 2025

in

IIT Kharagpur Research Park

Organized by IIT Kharagpur & SPSI

08.00 AM	Registration
09:00 - 09:05 AM	Invocation
09:05 - 09:10 AM	Welcome Adress by **Prof. Nikhil K. Singha**, **Convener, SPSI-MACRO 2025**
09:10 - 9:25 AM	Welcome address by **Conference Chairmen** **Prof. Joykrishna Dey**, **Prof. Susanta Banerjee** and **Prof. Kinsuk Naskar**
09:25 - 9:30 AM	Address by **Prof. Anil Kumar**, **President, SPSI**
09:30 - 9:40 AM	Address by **Prof. Suman Chakraborty**, **Director, IIT Kharagpur**
09:40 - 9:50 AM	Address by **Dr. S. Sivaram**, **Guest of Honour**
09:50 - 10:00 AM	Address by **Prof. Brigette Voit**, **Chief Guest**
10:00 - 10:10 AM	Award Ceremony
10:10 AM	Vote of thanks by **Prof. Dibakar Dhara**

Technical Schedule – Day 1

Time	Day 1, Monday, 15 December 2025
8.00 AM -9.00 AM	Registration
	Session-1 (9.00 AM-12.50 PM) Staudinger Hall (Main Auditorium)
9.00 AM -10.10 AM	Inaugural Event
10.10 AM -10.35 AM	Photo session, inauguration of Exhibition followed by Tea Break
10.40 AM-11.20 AM	PL-1: Prof. Brigitte Voit IPF Dresden, Germany
11.20 AM-11.50 AM	Prof. I K Varma Endowment Lecture: Prof. Padma Gopalan University of Wisconsin-Madison, USA
11.50 AM-12.20 PM	Prof. Santappa Award Lecture: Prof. Priyadarshi De IISER, Kolkata
12.20 AM -12.50 PM	Prof. Santappa Award Lecture: Prof. M. Jayakannan IISER, Pune
12.50 PM -2.10 PM	Lunch

Session-2 (2.15 PM -4.15 PM)					
Time	Staudinger Hall (Main Auditorium) Advanced Polymer Synthesis and Modification	Raman Hall (At 7th Floor) Polymer blends and Nanocomposites	Flory Hall (At 7th Floor) Sustainable polymer and processes	Goodyear Hall (At 8th Floor) Polymers and Elastomers for Energy & Electronic Applications	Palit Hall (At 8th Floor) Polymers in Paints, Coatings & Adhesives
2.15 PM- 2.45 PM	Prof. Holger Frey Johannes Gutenberg University Mainz, Germany KL-1	Prof. Aravind Vijayaraghavan University of Manchester, UK KL-2	Mr. SKP Amarnath Apollo Tyres, India KL-3	Dr. Debdatta Ratna DRDO, India KL-4	Mr. Lionel Schlessinger Monopol AG, Switzerland KL-5
2.45 PM- 3.10 PM	Prof. Sagar Pal IIT (ISM) Dhanbad IL-1	Prof. Sidhharth Sirohi University of Delhi IL-2	Prof. Grande Daniel Institute Charles Sadron,France IL-3	Prof. Leena Nebhani IIT Delhi IL-4	Dr. Tapan Dhar Berger Paints India Ltd IL-5

Technical Schedule – Day 1

Day-1 Session-2 (2.15 PM -4.15 PM)					
Time	Staudinger Hall (Main Auditorium) Advanced Polymer Synthesis and Modification	Raman Hall (At 7th Floor) Polymer blends and Nanocomposites	Flory Hall (At 7th Floor) Sustainable Polymers & Processes	Goodyear Hall (At 8th Floor) Polymers and Elastomers for Energy & Electronic Applications	Palit Hall (At 8th Floor) Polymers in Paints, Coatings & Adhesives
3.10 PM-3.35 PM	Dr. Asish Pal INST-Punjab IL-6	Prof. Aasheesh Srivastava IISER, Bhopal IL-7	Prof. Carbonnier Benjamin CNRS, France IL-8	Dr. Shreyam Chatterjee Osaka University, Japan IL-9	Dr. Debaprasad Mandal IIT Ropar IL-10
3.35 PM-4.00 PM	Dr. Ambade Ashootosh NCL Pune IL-11	Prof. Sarat K. Swain VSSUT, Orissa IL-12	Dr. Radek Stocek Tomas Bata University, Czech public IL-13	Dr. Dinesh Kotness IIT Patna IL-14	Dr. Arindam Chakraborty IICT, Hyderabad IL-15
4.00 PM-4.15 PM	Dr. Rajdip Roy RSC, India OL-1	Dr. Chandra. S. Verma AICTE, New Delhi OL-2	Dr. Senthil Andavan GT SRM-IST, Chennai OL-3	Mr. Mayank Varshney Waters Pvt. Ltd OL-4	Ms Anjlina kerketta CFEES, DRDO OL-5
4.15 PM -6.00 PM	Poster Session and Tea Break P-1 to P-100				
6.00 PM -7.00 PM	SPSI GBM at Raman Hall				
7.00 PM -8.00 PM	Cultural Program at Staudinger Hall (Main Auditorium)				
8.00 PM -10.00 PM	Gala Dinner				

Technical Schedule-Day 2

Day 2, Tuesday, 16 December 2025	
	Session-3 (9.00 AM-10.40 AM) Staudinger Hall (Main Auditorium)
9.00 AM-9.40 AM	PL-2: Prof. Nikos Hadjichristidis KAUST, Saudi Arabia
9.40 AM-10.10 AM	Prof. Kishore Memorial Award Lecture: Dr. Uttam Manna IIT Guwahati
10.10 AM-10.40 AM	Prof. Kishore Memorial Award Lecture: Dr. Sanjib Banerjee IIT Bhilai
10.40 AM-11.00 AM	Tea Break

Technical Schedule – Day 2

Session-4 (11.00 AM-1.15 PM)					
Time	Staudinger Hall (Main Auditorium) Advanced Polymer Synthesis and Modification	Raman Hall (At 7th Floor) Polymer Blends and Sustainable Nanocomposites	Flory Hall (At 7th Floor) Sustainable Polymers & Processes	Goodyear Hall (At 8th Floor) Next Generation Rubber and Polymer Materials in Energy Applications	Palit Hall (At 8th Floor) Additive Manufacturing in Polymers & Polymer Physics
11.00 AM-11.30 AM	Prof. Anil Kumar IIT Bombay KL-6	Dr. Kuruvilla Joseph IIST, Trivandrum KL-7	Prof. Pellegrino Musto National Research Council, Italy KL-8	Prof. Patric Jannasch Lund University, Sweden KL-9	Dr. S K Asha NCL Pune KL-10
11.30 AM-11.55 AM	Prof. Biswajit Ray Banaras Hindu University IL-16	Prof. Arup R. Bhattacharyya IIT Bombay IL-17	Prof. Abhijit Patra IISER Bhopal IL-18	Prof. E Murugan University of Madras, India IL-19	Prof. Himansu S. Nanda IIIT-Jabbalpur IL-20
11.55 AM-12.20 PM	Dr. Ranjita K. Bose University of Groningen, NL IL-21	Prof. Devasish Chowdhury IASST, Guwahati IL-22	Prof. Debashis Chakraborty IIT Madras IL-23	Dr. Amit Das IPF Dresden, Germany IL-24	Mr. Amit K Samanta Apar Industry ltd. India IL-25
12.20 PM-12.45 PM	Dr. Subrata Chattopadhyay IIT Patna IL-26	Dr. Debdipta Basu IRMRI, Kolkata IL-27	Prof. Bimlesh Lochab Shiv Nadar Institution , UP IL-28	Dr. Sutapa Ghosh IICT, Hyderabad IL-29	Mr. Manoj Bansal Thermofisher, India IL-30
12.45 PM-1.00 PM	Dr. Ramkrishna Sarkar IIT Kanpur OL-6	Dr. Mrinmoy Mondal CSIR-CSMCRI , Gujarat OL-7	Dr. Manjeet Singh BARC, Mumbai OL-8	Dr. Srinivasan Sampath Central University of Tamil Nadu OL-9	Dr. Arun Sikder SABIC, India OL-10
1.00 PM-1.15 PM	Dr. Manorama Tripathi CFEES, Delhi OL-11	Dr. Moumita Naskar CPRI, Kolkata OL-12	Dr. Pradeepa K G SJCE, Mysuru OL-13	Dr.Amrita Roy IRMRI, Thane OL-14	Dr.Suhas Mukherjee VSSC,TVM OL-15
1.15 PM- 2.15 PM	Lunch				

Day -2 Session-5 (2.15 PM-4.40 PM)						
Time	Staudinger Hall (Main Auditorium) Program on International Academic Collaboration	Time	Raman Hall (At 7th Floor) Advanced Polymer Synthesis and Modification	Flory Hall (At 7th Floor) Sustainable Polymers and Processes & Waste Management	Goodyear Hall (At 8th Floor) Polymers and Elastomers for Energy, Space and Defence Applications	Palit Hall (At 8th Floor) Polymers in Life science
2.15 PM-2.30 PM	Prof. Rabibrata Mukherjee IIT Kharagpur	2.15 PM-2.45 PM	Prof. Sanjay Rastogi KAUST, Saudi Arabia KL-11	Prof. Suresh Valiyaveettil National University of Singapore KL-12	Dr. Dibyendu Sekhar Bag DMSRDE DRDO, Kanpur KL-13	Prof. Subhas C. Kundu University of Minho, Portugal KL-14
2.30 PM-3.00 PM	Prof. Francesco Picchioni University of Groningen, Netherlands	2.45 PM- 3.10 PM	Prof. Tushar Jana University of Hyderabad, India IL-31	Dr. Andreas Leuteritz IPF Dresden, Germany IL-32	Dr. Pratyay Basak CSIR-IICT, Hyderabad IL-33	Dr. Ines Kuehnert IPF, Dresdren IL-34

Technical Schedule-Day 2

Day -2 Session-5 (2.15 PM-4.40 PM)						
Time	Staudinger Hall (Main Auditorium) Program on International Academic Collaboration	Time	Raman Hall (At 7th Floor) Advanced Polymer Synthesis and Modification	Flory Hall (At 7th Floor) Sustainable Polymers and Processes & Waste Management	Goodyear Hall (At 8th Floor) Polymers and Elastomers for Energy, Space and Defence Applications	Palit Hall (At 8th Floor) Polymers in Life science
3.00 PM-3.30 PM	Prof. Seema Agarwal University of Bayreuth, Germany	3.10 PM-3.35 PM	Dr. Nabanita Saha Tomas Bata University, Czech IL-35	Prof. Paramita Das IISER Bhopal IL-36	Prof. Umaprasana Ojha IIT Bhubaneswar IL-37	Prof. Amitav Sanyal Boğaziçi University , Turkey IL-38
3.30 PM-4.00 PM	Prof. Sven Wiessner IPF Dresden, Germany	3.35 PM-4.00 PM	Dr. Subrata Das CSIR- NIIST, TVM IL-39	Dr. Thomas Vidil CNRS, France IL-40	Dr. Uma Chatterjee CRIS-CSMCRI-Gujarat IL-41	Dr. M. Wahajuddin University of Bradford, UK IL-42
4.00 PM-4.30 PM	Prof. Stephen Rimmer University of Bradford, UK	4.00 PM-4.25 PM	Dr. Goutam Ghosh CeNS, Bangalore IL-43	Dr. Farsa Ram IISc Bengaluru IL-44	Dr. Prasun Roy DRDO, Delhi IL-45	Dr. Anurag Mukherjee Wiley-VCH GmbH IL-46
		4.25 PM -4.40 PM	Ms Surekha Parthasarathy CFEES, DRDO OL-16	Mr. Manish Kumar University of New South Wales, Australia OL-17	Ms Alips Srivastava CFEES, Delhi OL-18	Dr. Tanushri Banerjee IACS, Kolkata OL-19
4.40 PM-6.30 PM	Poster Session and Tea Break P -101 to P- 202					
6.30 PM-7.10 PM	Special Lecture By Dr. S. Sivaram (IISER Pune) Staudinger Hall (Main Auditorium) POLYMER SCIENCE AT THE CROSSROADS: WHERE DOES THE FUTURE LEAD?					
7.10 PM-9.00 PM	Dinner					

Technical Schedule-Day 3

Session-6 (9.00 AM-10.40 AM)	
	Staudinger Hall (Main Auditorium)
9.00 AM-9.40 AM	PL-3: Prof. Tony McNally WMG, University of Warwick, UK
9.40 AM-10.10 AM	Dr. Sivaram Endowment Lecture: Prof. Tanja Junkers Monash University, Australia
10.10 AM-10.40 AM	Prof. Palit Award: Prof. S. Ramakrishnan IISc Bangalore
10.40 AM-11.00 AM	Tea Break

Session-7 (11.00 AM-1.15 PM)					
Time	Staudinger Hall (Main Auditorium) Advanced Polymer Synthesis and Modification	Raman Hall(At 7th Floor) Polymer Blends and Sustainable Nanocomposites	Flory Hall (At 7th Floor) Polymer Waste Management	Goodyear Hall (At 8th Floor) Polymers and its composites in Paints, Coatings & Adhesives	Palit Hall (At 8th Floor) Polymers in Life Science
11.00 AM-11.30 AM	Prof. George Britovsek Imperial College London, UK KL-15	Prof. Y. Teramoto Kyoto University, Japan KL-16	Prof. Sadhan C. Jana University of Akron , USA KL-17	Dr. Satyasankar Jana ISCE2, A*STAR, Singapore KL-18	Prof. Pralay Maity IIT BHU KL-19
11.30 AM-11.55 AM	Prof. G. Unnikrishnan NIT Calicut IL-47	Prof. Ashok D. Mahapatra IIT Guwahati IL-48	Dr. Rahul Shingte Syensqo, India IL-49	Dr. Tapan Kumar Rout Tata Steel, India IL-50	Prof. Neil Cameron Monash University, Australia KL- 20 11.30 AM-12.00 PM
11.55 AM-12.20 PM	Prof. Roy Shenhar Hebrew University , Israel IL-51	Prof. Kausik Mukhopadhyay University of Central Florida, USA IL-52	Dr. Subhendu Ray Chowdhury BARC, Mumbai IL-53	Dr. G. Padmanaban Asian Paints Ltd. Mumbai IL-54	Dr. GVN Rathna NCL Pune IL-55 12.00 PM-12.25 PM
12.20 PM-12.45 PM	Dr. Priyadarshi Chakraborty IIT Hyderabad IL-56	Dr. Rama Layek LUT, Finland IL-57	Dr. Uttam K. Ghorai RKMV, Howrah IL-58	Dr. Anasuya Bandyopadhyaya IIT Roorkee IL-59	Dr. Amit Chakrabortty Reliance Ltd. India IL-60 12.25 PM-12.50 PM
12.45 PM-1.00 PM	Dr. Prantik Mondal University of San Diego, USA OL-20	Mrs Anju J VSSC, TVM OL-21	Dr. Archana Samanta IIT Delhi OL-22	Dr. Ikhlas Gadwal Asian Paints Ltd OL-23	Dr. Rosemary MJ HLL Lifecare Ltd. OL-24 12.50 PM -1.05 PM
1.00 PM-1.15 PM	Dr Mahipal Meena CFEES, DRDO OL-25	Dr. A B Hemavathi JCE, JSS STU, Mysore OL-26	Mr. Alexsandar Arumugam Technical University Clausthal, Germany OL-27	Dr. Girish Mirchandani Asian Paints ltd, Mumbai OL-28	Dr. Gayathri S VSSC, TVM OL-29
1.15 PM- 2.25 PM	Lunch				

Technical Schedule-Day 3

Day -3 Session-8 (2.25 PM – 5.05 PM)						
Time	Staudinger Hall (Main Auditorium) Advanced Polymer Synthesis and Modification	Raman Hall (At 7th Floor) Functional Polymers & Polymer Blend and Nanocomposites	Flory Hall (At 7th Floor) Modelling, Simulation and AI/ ML in Polymers & Polymer Physics	Goodyear Hall (At 8th Floor) Sustainable Polymers and Processes & Waste Management	Time	Palit Hall (At 8th Floor) Industrial Lectures
2.25 PM- 2.55 PM	Prof. Kana M. Sureshan IISER, Thiruvananthapuram KL-21	Prof. Christine Jérôme University of Liege, Belgium KL-22	Prof. Niloy Ganguly IIT Kharagpur KL-23	Prof. A K Nandi IACS, Kolkata KL-24	2.25 PM- 2.55 PM	Dr. R. Mukhopadhyay HASTERI, Mysuru KL-25
2.55 PM-3.25 PM	Prof. Raja Shunmugam IISER, Kolkata KL-26	Dr. Kartik Kumar Saint Gobain, India KL-27	Dr. E Bhoje Gowd CSIR-NIIST, India KL-28	Dr. Samir H. Chikkali CSIR, NCL-Pune KL-29	2.55 PM-3.25 PM	Dr. Jagabandhu Kole JSW Group, India KL-30
3.25 PM-3.50 PM	Dr. Alok Sarkar Momentive IL-61	Prof. Mangala Joshi IIT Delhi IL-62	Prof. Tarak Patra IIT Madras IL-63	Dr. A V Sainath CSIR-IICT IL-64	3.25 PM-3.50 PM	Dr. Narayan Ch. Mishra IIT Roorkee IL-65
3.50 PM-4.15 PM	Prof. Y. Matsuda Kogakuin University, Japan IL-66	Dr. Uday Shankar IIT BHU IL- 67	Dr. Eric Euchler IPF Dresden, Germany IL-68	Dr. Garim Agrawal IIT Mandi IL-69	3.50 PM-4.15 PM	Dr. Saptarshi Ray BPCL, India IL-70
4.15 PM-4.40 PM	Prof. Pradip Paik IIT BHU IL-71	Dr. Rajkumar Roy IISER Mohali IL-72	Dr. Ketan Patel CSIR-CSMCRI, India IL-73	Dr. Debasis Samanta CLRI, Chennai IL-74	4.15 PM-4.40 PM	Dr. Debarshi Dasgupta Momentive IL-75
4.40 PM-4.55 PM	Dr. Pintu Sar B N College, Bhagalpur OL-30		Mr. Nirmal C VSSC, ISRO OL-31	Dr Tirthankar Jana. Berger Paints India Ltd OL-32	4.40 PM-5.05 PM	Mr. Peram P. Rao Technobiz, Thailand IL-76
5.05 PM -6.55 PM	Poster Session and Tea Break P-203 to P-311					
7.00 PM -9.15 PM	Dinner					

Technical Schedule-Day 4

Day 4, Thursday, 18 December 2025

Session-9 (9.00 AM-10.35 AM)

Time	Staudinger Hall (Main Auditorium) Polymer in Biomedical Applications	Raman Hall (At 7th Floor) Sustainable Polymers & Processes	Flory Hall (At 7th Floor) Advanced Polymers and Nanostructures	Goodyear Hall (At 8th Floor) Polymer Additive and Characterization	Palit Hall (At 8th Floor) Elastomer Composites in Automotive Applications
09.00 AM-09.30 AM	Dr. Mijanur R Molla University of Calcutta IL-77	Prof. Vimal Katiyar IIT Guwahati KL-31	Prof. Tarun K. Mandal IACS, Kolkata KL-32	Dr. Anubhab Saxena Pidilite, India KL-33	Dr. Sujit Nair CEAT Ltd., India KL-34
09.30 AM-9.55 AM	Prof. Sampa Saha IIT Delhi IL-78	Dr. Sushanta K Sahoo CSIR-NIIST, Kerala IL-79	Dr. Samarendra Maji SRM-IST, Chennai IL-80	Mr. Moritz Goettfert GÖTTFERT GmbH IL-81	Dr. Sambhu Bhadra CEAT Ltd, India IL-82
9.55 AM-10.20 AM	Prof. Roli Purwar Delhi Technological University IL-83	Dr. Shilpi Kushwaha CSIR-CSMCRI, Gujarat IL-84	Dr. Jayanta Nanda University of North Bengal IL-85	Dr. Dhruba P. Chatterjee Presidency University , Kolkata IL-86	Dr. Tapas R. Mohanty Apollo Tyres . India IL-87
10.20 AM-10.35 AM	Dr. Paras Kalra BRAC, Mumbai OL-33	Dr. Atanu Jha BARC MUMBAI OL-34	Dr. Priyanka Dutta CSIR-National Physical Laboratory OL-35	Dr. Prosenjit Ghosh CSIR-NAL OL-36	Dr. Mayur Valodkar Apcotex Industries Ltd. Gujarat OL-37
10.35 AM-11.00 AM	Tea Break				

Session-10 (11.00 AM-12.30 PM)

Time	Staudinger Hall (Main Auditorium) Advanced Polymer Synthesis and Modification	Raman Hall (At 7th Floor) Polymer and Elastomer blends and Composites	Flory Hall (At 7th Floor) Polymer Waste Management: Recycling, Upcycling & Circular Economy	Goodyear Hall (At 8th Floor) Polymers in Space and Defence Applications	Palit Hall (At 8th Floor) Advanced Polymers in Paints, Coatings & Adhesives
11.00 AM- 11.15 AM	Dr. Dipankar Das Brainware University, Kolkata OL-38	Dr. Debabrata Ganguly CEAT Ltd., India OL-39	Dr. Sushanta K Sethi IIT Dharwad OL-40	Dr. Rajeev Rs VSSC.TVM IL-88 11.00 AM-11.25 AM	Dr. Bhuwanesh K. Sharma Plastindia International University, Gujarat OL-41
11.15 AM-11.30 AM	Dr. Tilottama Baisakhi TIFR Hyderabad OL-42	Dr. Arti Srivastava Guru Ghasidas Vishwavidyalaya, Chhattisgarh OL-43	Dr. Pravesh Kumar Indian Oil -R&D Centre OL-44	Dr. Anitha S. Nair VSSC,TVM OL-45 11.25 AM-11.40 AM	Dr. Sriparna De Brainware University, Kolkata OL-46
11.30 AM-11.45 AM	Mr. Vibhanshu Maurya Chonnam National University, South Korea OL-47	Prof Nagappan Rajendiran University of Madras OL-48	Dr. Raju Bej IIT Guwahati OL-49	Dr. Ayan Datta IACS, Kolkata OL-50 11.40 AM-11.55 AM	Dr Sunitha K VSSC, ISRO OL-51

Technical Schedule-Day 4

Session-10 (11.00 AM-12.30 PM)					
Time	Staudinger Hall (Main Auditorium) Advanced Polymer Synthesis and Modification	Raman Hall (At 7th Floor) Polymer and Elastomer blends and Composites	Flory Hall (At 7th Floor) Polymer Waste Management: Recycling, Upcycling & Circular Economy	Goodyear Hall (At 8th Floor) Polymers in Space and Defence Applications	Palit Hall (At 8th Floor) Advanced Polymers in Paints, Coatings & Adhesives
11.45 AM-12.00 PM	Ms. Darshana Deb JNCASR, Bengaluru, OL-52	Mr. Nallaperumal AM VSSC,TVM OL-53	Dr. Anumol S CFEES, Delhi OL-54	Dr. Akansha Dixit IIT Kanpur OL-55 11.55 AM-12.10 PM	Dr. Jit Sarkar CSIR-CLRI OL-56
12.00 PM-12.15 PM	Dr. Sonu Kumar Mahindra University, OL-57	Dr. Aritri Pal IACS , Kolkata OL-58	Mr. Mohit Sharma GFL, India OL-59	Dr. Haridas Kar University of Padova, Italy OL-60 12.10 PM-12.25 PM	Mrs Smitha Sukumaran VSSC, ISRO, TVM OL-61
12.15 PM- 12.30 PM	Dr. Pradip Dey Visva-Bharati University, India OL-62	Dr. Rani Rohini IIT Jammu OL-63	Ms. Khushboo Varshney BARC, India OL-64		Dr. Suryakanta Nayak Tata Steel Ltd OL-65
12.30 PM- 1.10 PM	Valedictory session Staudinger Hall (Main Auditorium)				
1.10 PM -2.30 PM	Lunch				

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PLENARY LECTURE

Polymeric optoelectronic and energy materials fine-tuned for application

Brigitte Voit*

Leibniz Institute of Polymer Research Dresden, Division Macromolecular Chemistry, Hohe Strasse 6, 01069 Dresden, Germany

The microelectronics industry, and especially the organic/flexible electronics industry, continues to demand new innovative polymeric materials. In our group we address this need by various approaches. Controlled polymerization techniques like Kumada-Catalyst-Transfer-Polycondensation allow to prepare polymeric semiconductors with precision structure under mild conditions with very low catalyst amount, resulting in very high molar mass products with low defects and improved performance, as well as being able to design the architecture and end group. In addition, synthetic procedures have been improved for various C-C coupling reactions to prepare e.g., fluorene, carbazoles, diketopyrrolopyrrole (DPP) or naphthaline diimide (NDI) based structures with improved performance, and adding features like crosslinking ability, reactive end functionality, and improved processing properties.

After a short overview at those activity, the lecture will specifically focus on tuning functional polymers for application in organic light emitting diodes. This will first cover new phenylphosphine oxide containing ambipolar host polymers for emitters. In addition, thermally activated delayed fluorescence (TADF) materials are discussed as one of the most promising future emitter materials in OLED. Switching towards solution processed OLEDs based on polymers poses also specific challenges. Highly aromatic polymers exhibit usually high thermal and mechanical stability but also limited solubility and processability. Introducing branching can solve this limitation. Well-soluble, branched high refractive index (HRI) aromatic HRI hb polymers will be introduced as effective polymeric out-coupling layer in OLEDs.

New conductive materials are also highly important in energy applications, like in batteries, supercapacitors or in thermoelectric generators. Especially conductive polymeric nanocomposites, e.g. using carbon nanotubes as filler, are highly relevant in these applications due to easy and affordable scaling and easy processing. Examples will be given in this regard.

From Challenge to Control: The Living Polymerization of Glycolide

Nikos Hadjichristidis*

King Abdullah University of Science and Technology (KAUST), Thuwal, 23955, Saudi Arabia

This study presents the first efficient living/controlled ring-opening polymerization (ROP) of glycolide (GL), a commercially available bioderived monomer, using strong protic fluoroalcohols (FAs) as cosolvents. Our research demonstrates that FAs not only enhance solubility but also activate both the monomer and living chain-end, as supported by density functional theory (DFT) calculations and NMR titration studies.[1] This innovative approach enables the synthesis of well-defined polyglycolide (PGA), (**Figure 1**) while facilitating the creation of novel PGA-based macromolecular architectures with unique properties.[2,3] Remarkably, the resulting PGA can be chemically recycled into its monomer with high selectivity and yield, offering a sustainable alternative to conventional non-recyclable polymers. This work also deepens our understanding of anionic ROP mechanisms, traditionally hindered by protic impurities. Results on methyl-substituted PGA will also be discussed.[4]

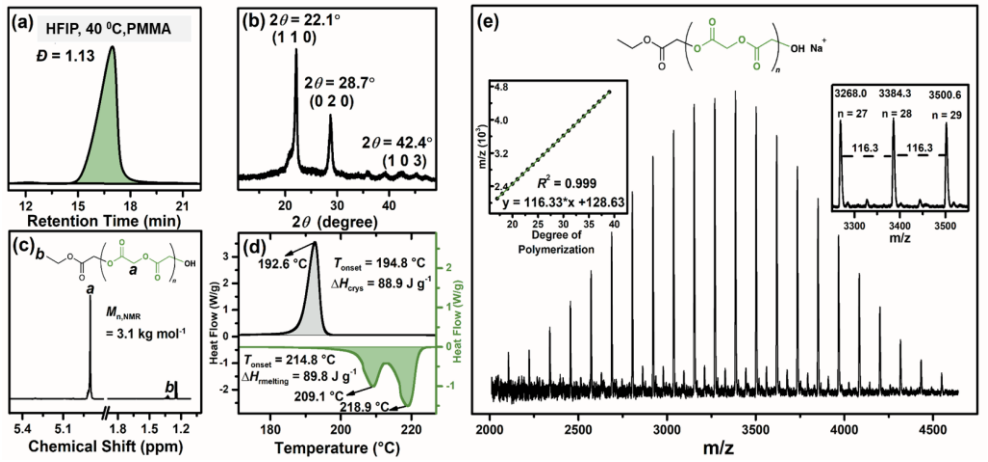


Figure 1. Molecular characterization of PGA **(a)** SEC trace, HFIP, 40 °C, PMMA standards. **(b)** WA-XRD pattern. **(c)** ^{1}H NMR spectrum (600 MHz, 298 K, $CDCl_3$/HFIP). **(d)** DSC scans (10 °C min^{-1}). **(e)** MALDI-TOF MS spectrum.

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Towards Useful Composites of 1D/2D Nanomaterials and Polymers

Tony McNally[a,*]

[a]*International Institute for Nanocomposites Manufacturing (IINM), WMG, University of Warwick, CV4 7AL, UK*

It is more than 30 years since carbon nanotubes were first synthesised and just over two decades since graphene was isolated by mechanical cleavage. Almost without exception, the first high volume application of such 1D and 2D nanomaterials, and many of their inorganic analogues, is as a functional filler for polymers, in the anticipation that the many unique intrinsic properties of these nanomaterials can be translated to different polymers. The optimal properties are mostly achieved by ensuring effective dispersion and distribution of the nanomaterial in the polymer matrix of interest. To date, the approach by many researchers has been to use ineffective mixing methodologies assisted with organic and other solvents that are not industrially relevant and are environmentally contentious. For composites of polymers and 0D/1D/2D materials to be useful an understanding of the shear and extensional forces required to effectively disperse and distribute nanomaterials in different polymers in the melt state is critical to obtaining a useful (nano)composite. Equally as important to manufacturing useful products is an understanding of the secondary processing of these composite materials as typically this requires a second thermo-mechanical step in the case of injection moulding or quasi-solid-state deformation in processes such as thermoforming or blow moulding. The other major consideration is that 1D and 2D materials are not monodisperse, can have high defect densities and high levels of impurities. Functionalisation of these materials is possible and required to promote interfacial interactions between filler and polymer, but in the case of graphitic based nanomaterials, many covalent approaches to functionalisation greatly alter the ratio of carbon sp2 to sp3 hybridisation which can result in a significant decrease in the electric and thermal conductivity of carbon nanotubes (CNTs) and graphene-based materials and introduce further defect sites. In this presentation, we will show how fully understanding the structure, morphology and surface chemistry of nanomaterials through extensive characterisation prior to inclusion in polymer melts is essential1-4 to achieving effective dispersion in different polymer systems. We also describe the different strategies available for functionalisation of nanomaterials showing how silane chemistry can be easily applied to modify the surface of 2D graphitic structures, including very low oxygen content, highly sp2 hybridised graphene nanoplatelets5-7. Promotion of interfacial interactions can also be achieved by reactive extrusion to produce lightweight composites8 or via polyelectrolyte complexation with natural polymers9 Finally, we demonstrate that the properties of (nano)composites are also determined from the effects the inclusion of the 1D/2D material has on changing the structure and morphology of the polymer matrix10.

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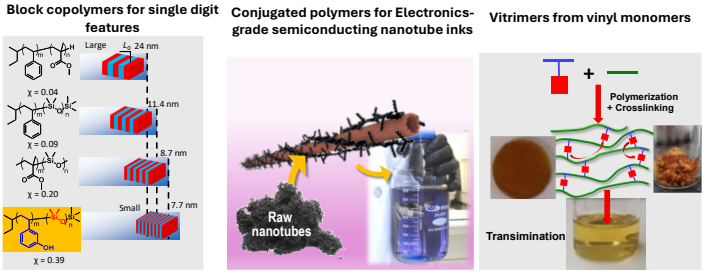
Polymer Design Encoded for Microelectronics and Recyclability

Padma Gopalan[*a]

[a] *Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, USA*

Over the last two decades my group has focused on polymers for microelectronics and optoelectronic applications. These include block copolymers that are synthesized with encoded information to define the size and shape of the resulting nanostructures which can then be used to pattern dense periodic lines and dots to access single digit features in a scalable, cost-effective manner for device fabrication[1, 2]. Concurrently we have pursued the design of conjugated polymers to enable high speed electronics beyond silicon, by assembling a monolayer array of single walled carbon nanotubes(SWCNTs) with 5-10 nm pitch for field effect transistors and RF amplifiers. These conjugated polymers have many functions embedded in the structure such as ability to selectively sort semiconducting CNTs from a heterogenous mixture, degradability for easy removal after device fabrication, and self-assembling characteristics to define the pitch between the tubes. I will highlight the latest advances made by our team in this area[3-5].

The second part of my talk will focus on a new type of vitrimer that we have developed recently that can be made from any commercial vinyl monomer using a free radical mechanism. Vitrimers bridge the gap between thermoplastics and thermosets to address the trade-off between recyclability and thermomechanical properties by incorporation of dynamic covalent bonds in the network structure. The polyimine vitrimers that we have developed show superior creep resistance, improved Youngs modulus, and hardness. Our approach bypasses amine-aldehyde condensation, hence expanding the monomer scope. I will present detailed stress relaxation experiments and oscillatory shear experiments to fully characterize the viscoelastic properties of the vitrimers. We further show that transimination reaction can effectively reprocess the vitrimers, while offering the advantage of increased resistance to hydrolytic degradation. Our methodology decouples polyimine vitrimers design from monomer limitations, providing a scalable route to tailoring high-performance vitrimers.



Figures 1: Overview of topics in polymer design for microelectronics and vitrimers covered in the talk

Keywords: Block copolymers, Microelectronics, Vitrimers, Carbon Nanotube Inks, Reprocessible.

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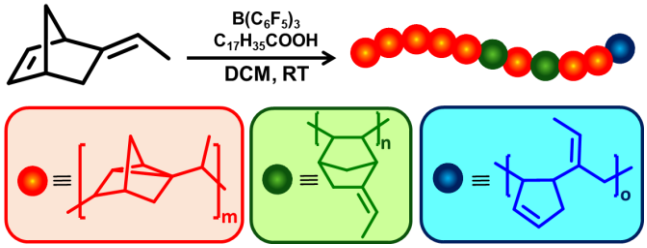
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Synthesis of High-Performance Norbornene-Based Polymers *via* Cationic Polymerization

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In recent years, norbornene-derived polymers have garnered increasing attention in both academic and industrial settings due to their excellent mechanical strength, thermal stability, low birefringence, desirable membrane characteristics, and high optical transparency.[1] These polymers can be synthesized through various pathways,[2] among which cationic polymerization remains relatively underexplored.[3] In this study, we investigate the cationic polymerization of norbornene derivatives, catalyzed by $B(C_6F_5)_3$ under modified reaction conditions (see Scheme 1). While previous reports commonly employed toluene as the solvent and octanoic acid as the co-initiator, our approach utilizes dichloromethane (DCM) and stearic acid, leading to a marked improvement in monomer conversion and polymer yield. The superior performance observed in DCM is likely due to enhanced stabilization of the active cationic species, while the increased steric bulk of stearic acid appears to reduce chain transfer and termination, enabling more controlled polymer growth.[4] These findings highlight the critical influence of solvent polarity and co-initiator structure on the efficiency of cationic polymerization and present a promising strategy for optimizing the synthesis of high-performance norbornene-based polymers.



Scheme 1. Cationic polymerization of norbornene derivatives.

Keywords: Cationic polymerization; norbornene; $B(C_6F_5)_3$ catalyst; chain transfer and termination

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Biodegradable Block Copolymer Nanoarchitectures for Cancer Treatment

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Polymeric nanomaterials are emerging as important platform in biomedical research for drug delivery in cancer treatment. Structural engineering of polymeric biomaterials is still a challenging task specifically to overcome the tightly regulated biological conditions to delivery therapeutic drugs for solid tumor suppression in cancer research. Conventional polymer nanocarriers are predominantly multi-molecular (or many chain) nano-assemblies; thus, their aggregated micelle nanoparticles often exhibit premature disassembly in the bloodstream followed by the dilution imposed on them during IV injections. Further, the nano-assemblies are exposed to stress by the cardiac pumps and also by the renal filtration apparatus in kidney from the point. Therefore, the next generation nanocarriers are mandatorily designed to be substantially stable to evade disassembly in body fluidics *in vivo*, tiny-size sub-nanometer size-objects for penetrating the hard-tumor, high drug loading content, and most importantly biodegradable under physiological conditions for safe administration. Efforts have been taken in our lab to design and develop fully biodegradable polycaprolactone based linear block copolymers for delivering clinically important anticancer drugs DOX and cisplatin in-vitro.[1-2] We have noticed that tweaking the topology of the linear and branched macromolecular architectures was found to be very crucial factor in designing the nanocarriers, particularly single polymer chain nano-vectors like unimolecular micelles to impart stability against concentration gradient for their successful action under in-vivo. For this purpose, hydrophobic polycaprolactone (PCL) and carboxylic substituted hydrophilic PCL segments were chosen core and shell, respectively, in star-block copolymer design to get the right polymer geometry for unimolecular micellar self-assembly in water. The tailor-made star-block copolymers provided well-defined core-shell unimolecular micelle nanoparticles for high drug loading (14 %) and also maintain the drug NP against concentration gradient in the bloodstream.[3] Auto-degradation or self-immolative polymer concept is also imbibed to maximize the synergistic stimuli-responsiveness at the intracellular level for drug delivery.[4] The star unimolecular micelle nanoparticle platform was found to be non-toxic, non-hemolytic and antifouling, and also exhibited excellent drug action in multiple cancer cell lines at substantially low IC_{50} values. The unimolecular micelle platform is further validated for solid tumor suppression in Pancreatic cancer tumor-bearing mice model.[5] Currently efforts are taken expand the scope of the scaffolds to breach blood brain barrier for the treatment of glioblastoma (brain tumor). Our efforts open new avenues for unimolecular micelle nanoplatform in drug delivery, and the presentation will provide detail account on our contribution in this field.

Keywords*:* Block copolymers, Biodegradable polymers, Cancer Research, Drug Delivery, Tumor Models

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Smart Polymeric Surfaces with Rewritable and Liquid-Selective Wettability

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The nature-inspired wettabilities that either extremely repelled or allowed effortless sliding of different liquids (oil/water) in air or underwater are with immense potential for various prospective applications. In common practice, essential chemistry and appropriate topography that conferred the special liquid wettabilities were mostly and generally achieved by associating delicate chemistry. Eventually, the synthesized materials suffered from poor durability issues. In the literature, very few designs are capable of providing durable bio-inspired wettability—but fabrication processes remain generally complex. Moreover, the integration of various other relevant physical properties with such durable liquid wettability is highly challenging to achieve. Hence, design of robust bio-inspired liquid wettability following a simple fabrication process that would allow to integrate different and relevant physical properties is utmost important for various fundamental and applied contexts. Related to this, recently, our research group has extended 1,4-conjugate addition reactions between amine and acrylates at ambient conditions for systematic and orthogonal tailoring of topography and surface free energy to derive a range of functional materials embedded with a wide range of bio-inspired wettability having immense potential in a wide range of applications related to environment, health and energy.[1-10] In this lecture, I will reveal fundamental parameters that control slippery property on solid surface and strategy for developing smart polymeric surfaces with rewritable and liquid-selective wettability.[2]

Keywords: Polymeric material, liquid wettability, 1,4-conjugate addition reaction, rewritable, reactive coating

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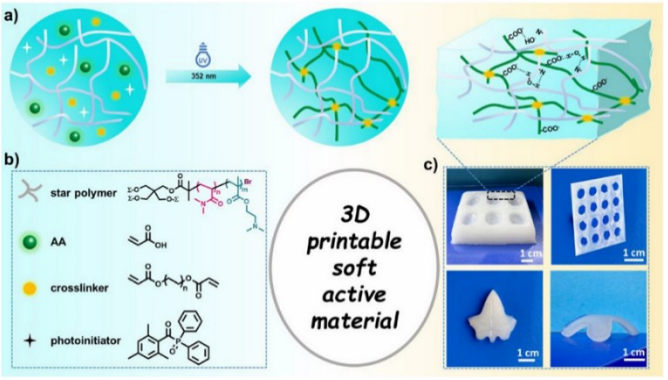
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Facile Photopolymerization Towards Smart Injectable Ink for 3D Printing Applications

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Current advanced 3D printing necessitates functional inks capable of rapid, mild fabrication. On the other hand, photopolymerization-based strategies offer a versatile platform for designing advanced materials with precise spatiotemporal control. We introduce a facile photopolymerization strategy for synthesizing novel smart injectable inks, overcoming limitations of conventional materials. The formulated inks exhibit rapid photo-crosslinking, shear-thinning behavior, and tunable mechanical properties, enabling high-resolution printing with structural fidelity. Moreover, the system demonstrates responsiveness to external stimuli, broadening its utility in biomedical scaffolds, soft electronics, and personalized devices. This approach provides a scalable and sustainable pathway to next-generation printable materials, bridging the gap between functional design and practical applications in additive manufacturing.



Figures 1 – a) Schematic diagram illustrating the preparation of a hydrogel, b) chemical structures of the precursors for 3D printing, c) 3D printed objects such as sheet, leap, and star shape.

Keywords: photopolymerization, star polymer, smart polymer, soft material, 3D printing.

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Automation in Polymer Synthesis: From Flow to Liquid Handling

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Chemistry, including the subdomain of chemical synthesis is rapidly adopting modern machine learning (ML) methodologies, as evidenced in many examples ranging from AlphaFold to the introduction of fully robotic laboratories for exploration of chemical spaces. However, in order to harness the power of ML, consistent and standardized data is required in quantity. Traditionally, chemical datasets, especially concerning synthesis of compounds, are fairly small, prohibiting the use of advanced ML algorithms. Thus, it is mandatory to improve data generation first, before more meaningful deep learning methodologies can be applied.
Unfortunately, human operation in a chemical synthesis lab is not only slow, but also prone to human bias and error. Even with skilled operators, synthesis outcomes often are not reproducible, since also glassware and exact reaction conditions are not standardized. A key to overcome these hurdles is the introduction of robotic synthesis. Robots are able to carry out tasks reliably and reproducibly in algorithmic fashion. Yet, the introduction of robotic systems to chemical laboratories is generally slow, due to the high technical implementation hurdle.

In this talk we will discuss what exactly constitutes a robot, and how robotics and automation can be used in everyday tasks efficiently, with an emphasis on simple systems. Specifically, we will look at continuous flow machines and at liquid handlers. The workflow of these relatively simple and quite affordable setups will be discussed, possibilities and challenges identified, and some recent examples given on the example of high throughput polymer synthesis, efficient kinetic screening and generation of libraries of materials. Flow chemistry is particularly suited towards self-driving labs that perform automatic self-optimizations in a closed loop. Liquid handlers, and their massive parallelization of reactions, provide an excellent tool for kinetic screenings and property evaluations. Based on these examples, we will also delve into the prediction of new materials based on ML analysis of the obtained datasets.

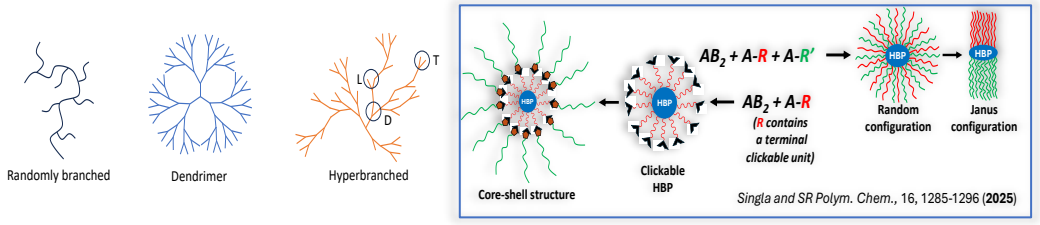
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My Fascinating Encounters with Hyperbranched Polymers

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In 1990, my first PhD student and I began working on a *then* relatively new class of polymers, namely Hyperbranched Polymers (HBPs), that were architecturally very distinct from simple linear polymeric chains and therefore were expected to exhibit several unusual properties, some of which had been seen in their structurally perfect congener, namely Dendrimers;[1] the area clearly presented numerous synthetic possibilities, structural variations and functional properties, all of which excited us. However, little did I imagine that my fascination with this class of polymers would last so long, that my last PhD student is utilizing HBPs to develop unique multi-domain crosslinked polymeric materials in order to



understand the impact of subtle structural features on their mechanical behavior.

Figure 1. Different types of branched architectures (left); direct preparation of Janus and core-shell amphiphilic HBPs (right).

Although our lab's research efforts strayed into several other interesting and rewarding areas, HBPs remained a unique and interesting thread that strung my academic career. For the Professor S R Palit Memorial Lecture, I will explore the question: *what is it that kept me glued to area of HBPs?* My talk will discuss a few fascinating snippets of some early unique revelations about HBPs and develop a story that would bring us to the most recent interesting discoveries that we made and are continuing to explore. Some of the recent findings that I will cover concern *Janus* amphiphilic HBPs,[2] Core-shell HBPs,[3] amphiphilic hydrogels,[4] single-ion conductors, and so on.

Keywords: Hyperbranched polymers; Janus structures; core-shell amphiphilic polymers; thermo-responsive polymers.

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SPECIAL LECTURE

Polymer Science At The Crossroads: Where Does The Future Lead?

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Polymer science is a new sub-discipline of science, about a hundred years old. Post-fifties polymers became key products of the burgeoning petrochemical industry, driven by inexpensive petroleum feedstocks. From mere curiosities, polymers have become an indispensable part of our daily life and are so ubiquitous that we hardly realize how dependent we are on polymers today. Polymer science has had an enviable past, contributing to the discovery of several new-to-the-world organic materials in a short span of fifty years, which serve critical functions in diverse applications, such as health, mobility, energy, natural, as well as the built environment. Today, we consume half a billion tons of synthetic polymers, which is slated to increase threefold by 2050. The emergence and growth of an industry of this size and scope in such a short span of time is unprecedented in history and is a testimony to the versatility and utility of polymer materials.

Polymer science is at the end of one wave of development, and as a stand-alone discipline, it has reached maturity. The synthetic toolboxes available to chemists have been refined; so much so that synthesizing a polymer molecule with precision, both at the molecular and supra-molecular level, is no longer a challenge. Our understanding of physical chemistry and the physics of polymers is comprehensive, and it is now possible to computationally predict properties of polymers. Most of the major challenges facing this discipline today appear to be at the interface of polymer science with other disciplines, such as advanced materials, biology, medicine, or physics.

As we conclude the first century of polymer science, it is pertinent to ask what the future challenges facing polymer science are. How will this science address some of the most challenging problems facing our society today in terms of fossil fuel use, low-carbon intensity materials, and energy? What are the technological fronts and scientific frontiers? What are the barriers to introducing new materials into the market? Can we define some holy grails of polymer science? The lecture will attempt to seek answers to some of these questions.

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KEYNOTE LECTURE

Isomerization of poly(ethylene glycol) to rPEG: A strategy for the evasion of immune recognition and for amorphous polyethers

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Polyethylene glycol (PEG) is the gold standard in pharmaceutical and nanomedicine applications based on its chemical inertness, aqueous solubility, biocompatibility, and unique stealth properties. Randomized PEG (rPEG) technology[1] has been designed to strongly reduce the antigenicity of PEG while preserving its pharmaceutical core benefits. Our conceptually novel approach is based on an ideally random introduction of hydrophilic side chains along the PEG backbone via copolymerization of ethylene oxide with glycidyl methyl ether (GME), as shown in Figure 1. This effectively diminishes antigen recognition by anti-PEG antibodies. However, all fundamental pharmaceutical properties of PEG are preserved, which is due to all copolymers being structural isomers of PEG, regardless of their composition.[2] The rPEG strategy also gives access to non-crystalline PEG-like materials for a broad range of biomedical materials. The approach can rely on existing PEG technology at every stage, allowing for the use of established GMP manufacturing processes and supply chains. rPEG is conveniently combined with lactide to PLA-based di- and triblock copolymers with elastic properties for biomedical application as controlled release systems. In addition, rPEG leads to promising Li-ion conducting polymer structures based on the amorphous nature of the materials, which opens additional fields of application for these PEG isomers in the field of batteries.

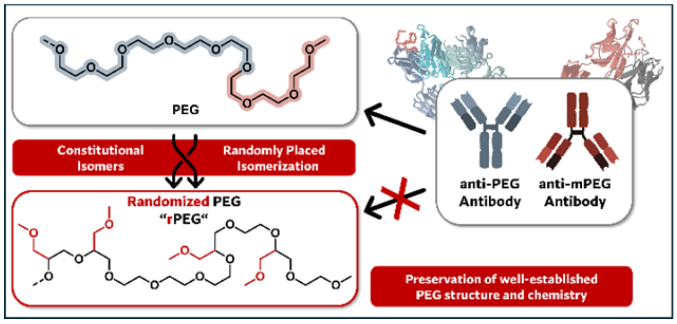


Figure 1: PEG isomerization to non-antigenic rPEG structure

Keywords: poly(ethylene glycol), PEGylation, nanomedicine, biomaterials

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Graphene Surface Engineering and Applications in Sensors, Composites and Water Purification

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Graphene and its derivatives offer exceptional mechanical, electrical, and chemical properties, enabling transformative applications across multiple sectors. Our research focuses on engineering graphene surfaces and interfaces to exploit these properties in advanced technologies. In sensors, we develop graphene-based layered composite membranes for MEMS/NEMS devices and electronic platforms with high sensitivity and selectivity, leveraging graphene's tuneable conductivity and functionalisation for biomedical and environmental monitoring. For structural applications, we design graphene-polymer nanocomposites and elastomeric foams with enhanced mechanical strength, thermal stability, and multifunctionality, addressing challenges in aerospace and energy sectors. In water purification, we pioneer the fabrication of graphene oxide aerogels and hydrogels with hierarchical porosity and tailored surface chemistry, achieving high flux and fouling resistance in filtration membranes and adsorptive removal of contaminants. Recent work includes the creation of 3D graphene "smoke ring" aerogel particles via controlled interfacial assembly, offering efficient pollutant capture through optimised surface interactions. These studies demonstrate how surface engineering strategies, such as chemical functionalisation, dispersion control, and bottom-up assembly, unlock graphene's potential for sustainable technologies. Our findings contribute to scalable solutions for global challenges in clean water, smart sensing, and lightweight composites.

Digital transformation and data advancement in the modern tire industry

Amarnath SKP

The global tire industry is at a pivotal inflection point, driven by the convergence of changing mobility demands (EVs, autonomous vehicles), the need for sustainable practices and Industry 4.0 technologies, This keynote presentation will cover how digital Transformation and the effective leverage of Big Data and AI are fundamentally reshaping the value chain from R&D to final product use.

Polymer Nanocomposite-based membranes for Fuel cells and Water Electrolyser Applications

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For the pursuit of total carbon neutrality, clean energy generation emerges as the most vital transformation pillar, especially the advanced electrochemical technologies including fuel cell and water electrolyser which together form the backbone of the emerging hydrogen economy. Among various types of fuel cells Proton exchange membrane-based fuel cells (PEMFC) holds particular prominence due its efficiency, compactness and versatility. PEMFC are categorized into two major subtypes: Low temperature PEM fuel cell (LTPEMFC) and High temperature PEM fuel cell (HTPEMFC). The LTPEMFC typically operates between 60°-80°C using perfluorosulfonic acid polymer membrane such as Nafion as electrolytes. But due to low temperature, it faces several drawbacks including CO poisoning of cathode catalyst, fuel impurity, inefficient water and heat management etc. which all have been addressed by HT-PEMFC (high temperature PEM fuel cells). They operate at 150°-200°C, eliminating the need for external humidification and simplified system design. PBI and ABPBI due to there good mechanical property, thermo-oxidative stability, have been widely used as PEM in fuel cells, by doping with phosphoric acid (H_3PO_4).

In our laboratory, we have developed various composite membranes by incorporating different nano-fillers in ABPBI membrane in order to further enhance the conductivity, mechanical and thermal stability of the membranes. The incorporation of the ZrP nano-filler enhanced the proton conductivity of the ABPBI by providing the additional sites for H+ transportation. We have successfully demonstrated 100 W, 300 W and 500 W fuel cell stacks using these nanocomposite membranes with satisfactory results. Also, we have incorporated polyhedral oligomeric silsesquioxane (POSS) and sulfonated polyhedral oligomeric silsesquioxane (SPOSS) nano-filler in order to enhance the mechanical properties and oxidative stability during long term usage in the fuel cell system at high temperature. The SPOSS based nanocomposite membrane performed better by reducing acid leaching, less prone to oxidative degradation and thus an overall enhanced performance. Utilisation of ABPBI as ion solvating membrane for electrolyser application has also been investigated by doping with KOH. We have demonstrated that by incorporating optimum concentration of POSS it is possible to enhance the conductivity and stability of such membranes ensuring their suitability for water electrolyser application.

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Sustainable Corrosion and Color Protection: ISO 12944 with Fluoropolymer Coatings

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Corrosion is a ubiquitous problem that costs between 3% and 5% of GDP, depending on the country. It affects not only the economy but also the environment and society. Therefore, improving corrosion protection for both substrates and coatings is crucial. FEVE coatings enhance the resilience of corrosion-protective systems. With the introduction of ISO 12944:2018, a new protection category - “very high,” defined as a service life of more than 25 years — was established. This service life refers exclusively to corrosion resistance; it does not account for the coating’s aesthetic appearance or for potential loss of performance due to porosity resulting from chalking. In structures such as bridges, where a complete overhaul is often deferred until 30–40 years after construction, final coatings frequently cannot meet both functional and aesthetic requirements for such extended periods. Practical examples and cost analyses will demonstrate that modern fluoropolymer coatings can achieve a “very high” service life both functionally and aesthetically. The presentation will also address the PFAS debate and explain why these fluoropolymer systems can be used safely without posing an environmental hazard.

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Manufacturing of Next Generation of Smart and Conjugated Polymers via Continuous Process Intensification

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ABSTRACT

The art and science of organic synthesis coupled with chemical manufacturing is undergoing tectonic shift due to the recent developments in continuous process intensification via Flow, Electro, photo and Mechano Chemistry. Continuous process provides a potential alternative to batch synthesis because of its inherent advantages such as very efficient heat exchange, high batch to batch reproducibility, fast mixing, high throughput, safety, and the ability to do multistep telescoping synthesis. Due to these advantages, these processes have been referred to as the most promising "Green Technology". In fact, continuous flow processes are projected to be the "CHEMICAL FACTORIES" of tomorrow. Continuous flow processes also provide an "On-Demand" synthesis with complete control over reproducibility, size, shape and these parameters can be achieved at various scales (lab synthesis to pilot to bulk production) with excellent reproducibility. It also enables one to carry out chemical manufacturing without solvents or even without reagents. We have been exploring these continuous processes for the synthesis of smart, functional and conjugated polymers, nanoparticles and nanofibers and more. In this presentation, I will review some of the recent advances in these directions and some results from our laboratory.

KEYWORDS

Continuous Process Intensification; Conducting Polymers; Transparent Conductors, Electrochromics

BIOGRAPHY

Anil Kumar is currently a Professor at IIT Bombay, in the Department of Chemistry. He also serves as President of the Society for Polymer Science, India. His group's research interests are in the area of Process Intensification, Optoelectronic Devices and Materials, Nanomaterials, Flavors & Fragrance, polymers, and Continuous Crystallization. His group has also developed many technologies including transfer of technology in the domain of handheld explosive sensors and continuous flow processes. For his contribution in this field, he has been awarded with the 2017 NASI-RIL Platinum Jubilee National Award for application-oriented innovations.

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Design and Development of Polymer Nanocomposites for EMI Shielding and Smart Reprocessable Thermoset Materials

Kuruvilla Joseph*

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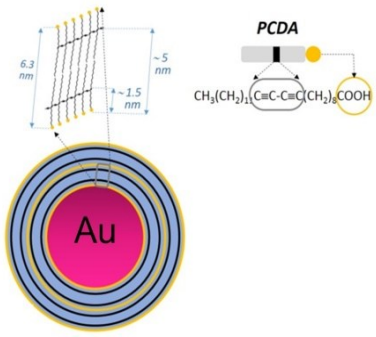
Electromagnetic interference (EMI) has become a critical concern in modern electronic and communication systems, creating an urgent demand for lightweight, flexible, and high-performance shielding materials. Polymer-based nanocomposites and aerogels have recently emerged as promising alternatives due to their low weight, structural tunability, and multifunctional capabilities. Electrospinning and freeze-drying techniques were employed as complementary fabrication strategies in the current study to produce fibrous and porous architectures, respectively. Electrospun fibers of polyimide, poly(styrene-co-butadiene), and carbonized polyacrylonitrile were reinforced into epoxy matrices to enhance mechanical performance and electrical conductivity. The combination of high aspect ratio fibers and interconnected porous structures facilitated multiple EMI attenuation mechanisms, including reflection, absorption, and interfacial polarization losses. These materials also exhibited excellent thermal stability and low density, making them suitable for applications requiring structural and functional integration. Overall, the study aims to establish structure–property correlations in polymer nanocomposites and aerogels to achieve lightweight, mechanically robust, and thermally insulating EMI shielding materials for potential use in aerospace, defence, and advanced electronic systems.

Polymer-Metal Core-shell Hybrids: Multifunctional Nanostructures For Theranostic Applications

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The design of elaborate nanostructures that integrate diverse materials into hybrid systems is being actively pursued to develop functional platforms capable of meeting the demands of rapidly advancing technologies. In particular, polymer-coated nanoobjects, have demonstrated great potential in numerous applications including energy harvesting, catalysis and nanomedicine. In the biomedical field gold nanospheres surrounded by a polymeric layer with controlled architecture provide significant advantages such as enhanced cellular uptake, reduced cytotoxicity, structural stability, and an ensemble of functional properties leveraging the strong and tunable plasmonic response of the inner core [1]. Here we report on the synthesis and molecular characterization of one of such hybrid nanostructures, obtained by coating gold nanoparticles with poly(10,12-pentacosadiynoic acid, pPCDA) via *in-situ* photopolymerization [2]. A schematic illustration of the Au@pPCDA architecture is shown in Figure 1A. The synthetic route affords precise control of the Au core size in the 3–80 nm range, where the plasmonic resonance is strong and tunable. These colloids exhibit thermosensing properties – rooted on the conformational switching of the outer shell – with a sensitivity of 0.11 $cm^{-1}/°C$ in the 25–125 °C range. Under 638 nm laser irradiation, these constructs produce strong SERS signals, enabling sensitive and high-contrast Raman imaging. After 6 h incubation in human prostate cancer cells (PC3), significant uptake was achieved [$(5 \pm 1.1) \times 10^4$ counts/μm^2], and intracellular temperature monitoring was successfully demonstrated [3]. Moreover, upon prolonged laser irradiation, the nanostructures acted as efficient light-to-heat transducers, inducing localized temperature increases exceeding 125 °C in tumor cells (Figure 1B). This thermoplasmonic effect becomes more pronounced as the Au core size increases, in agreement with theoretical predictions [4]. By combining thermoplasmonic, thermosensing, and imaging functionalities, polydiacetylene-coated Au nanospheres emerge as promising multifunctional theranostic agents for cancer imaging and therapy.



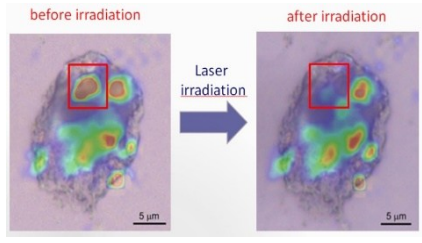


Figure 1: *A) Schematic representation of Au@pPCDA nanostructures; B) superposition of Raman image with the relative dark-field optical micrograph of a PC3 cell incubated for 6 h, recorded before and after laser irradiation.*

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Synthetic approaches to anion-exchange membranes *via* polyhydroxyalkylations

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Abstract: Extensive research is currently being conducted to develop anion exchange membranes (AEMs) with high hydroxide conductivity and chemical stability, aiming to increase efficiency and lifetime of alkaline membrane fuel cells, water electrolyzers, and flow batteries.[1] In this context, poly(arylene alkylene)s have recently emerged to offer great opportunities and flexibility to molecularly design and prepare tunable and robust AEMs with high performance and longevity.[2] This class of polymers is prepared by superacid-mediated Friedel-Crafts-type polyhydroxyalkylations, typically involving a ketone or an aldehyde, and an arene such as biphenyl and terphenyl. My research group has over the past 8 years studied poly(arylene alkylene)s and, for example, reported on the first poly(aryl piperidinium) AEMs, demonstrating high alkaline stability and hydroxide conductivity.[3]

In the current presentation, different synthetic strategies to tune and improve the preparation, properties, and performance of poly(arylene alkylene) AEMs functionalized with *N*-alicyclic quaternary ammonium cations will be discussed. This includes variation of the polymer structure by incorporating xanthene (Figure 1a), quaterphenyl (Figure 1b), and fused-benzene-ring units such as chrysene (Figure 1c).[4] In addition, AEMs functionalized with novel ionic groups, such as zwitterionic *N*-sulfoalkylquinuclidinium groups (Figure 1d), will be discussed.[5]

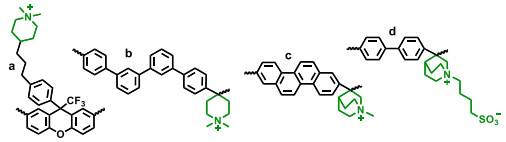


Figure 1. Various synthetic strategies for high-performance AEMs: piperidinium-functionalized poly(xanthene) (a), poly(*m,m*-quaterphenyl piperidinium) (b), poly(chrysene quinuclidinium) (c), and poly(aryl alkylene) with zwitterionic groups (d).

Keywords: polycondensation, ion-exchange membrane, alkaline stability, ionic conductivity, energy conversion and storage

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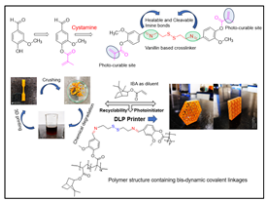
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Exploring Recyclable Photocurable Resins for 3D Printing Application.

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Additive Manufacturing (AM) or 3D printing (3DP) has evolved into a multifaceted technology platform for computer-assisted design (CAD) and rapid manufacturing. The swift progress in AM machinery technology over the last decade has spurred the quest for appropriate materials that can fulfil the requirements of these applications. In our research group, we are focused on creating photo-curable cross-linkers derived from bio-derived materials.[1-4] The primary challenge lies in developing materials that provide adequate mechanical strength to the 3D printed objects while also being suitable for formulation into a freely flowable mixture for light-based 3D printing technologies like the Digital Light Processing (DLP) and Stereo lithography (SLA). The 3D Printing of polyether ether ketone (PEEK), which is a high-performance thermoplastic polymer, at room temperature presents significant challenges. We have formulated modified PEEK polymers that incorporate urethane acrylate end groups. Our report marks the first instance of room temperature DLP 3D printing of functionalized PEEK polymers, which demonstrated approximately 55 % of the Young's modulus found in 3D printed commercial PEEK polymers.3 The development and creation of materials that combine the 3D printing of polymers with the recyclability of thermoset materials produced through 3D printing has emerged as a fascinating research domain. Materials that incorporate covalent adaptable network (CAN) chemistry, which facilitates recycling, show significant promise. In my presentation, I will discuss the ongoing research efforts in my group aimed at developing bio-based, solvent-free 3D printable formulations that also demonstrate self-healing ability and shape memory effects.[4]



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Crystallization during polymerization; Tailoring of non-crystalline region in semi-crystalline polymers

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Mechanical and physical properties of the polymers are strongly influenced by the molar mass and molecular configuration. It is also realized that at the segmental length scale, because of the feasible variability of the topological constraints, non-crystalline region in a semi-crystalline polymer is least well understood. This imposes challenges and provides new opportunities in polymer science having technological implications. The colloquium, split in two parts, will demonstrate the influence of topological constraints on segmental mobility in the crystalline domains, response of the crystals invoking melting kinetics, flow ability of crystals on compression in solid state, and the resultant non-equilibrium polymer melt.

Bringing in the examples of polyethylene, polypropylene, polyketones, trans 1,4-polybutadiene, poly-4-methyl pentene-1, and isotactic polystyrene, the paper will bridge the influence of polymerization conditions, and understanding of crystallization during polymerization, to achieve the ultimate mechanical properties in the intractable ultra-high molecular weight polymers. This colloquium will address the concepts of solvent-free solid-state processing. The unique solvent-free processing overcomes challenges of the use of solvents in the development of uniaxial and biaxial products having unprecedented properties.

Keywords: polymerization, polyolefin, crystallization, kinetics, solid-state processing

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Functional polymers for sustainable processes and technologies

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Nature has developed highly sophisticated methods for synthesizing multifunctional and sustainable polymers such as cellulose and proteins. Such polymers show hierarchical architectures with built-in circularity and sustainability via both highly functional polymer backbones and controlled self-assembly. Life on Earth depends on such defect-free and reproducible polymer synthesis for survival and continued growth. Mimicking or learning biopolymer synthesis is difficult; therefore, the industry chose linear polymer synthesis routes to meet the demands of our daily lives. However, the waste generated from the extended use of synthetic polymers is difficult to recycle or sustain the resources. For example, the widespread usage of plastic products and poor recyclability have led to the accumulation of plastic waste in the environment. The discarded plastics undergo degradation to release small particles (i.e., microplastics) and chemicals into the environment. To bring circularity and sustainability to precious resources, we need new approaches towards material design and synthesis. We are interested in developing new sustainable materials and learning how plastic waste interacts with living organisms, including humans. Our approach towards sustainable materials includes developing new circular synthetic polymers and modifying existing biopolymers. For understanding the impact of plastics on human health, a few in vitro and in vivo model systems were used to understand the interactions and toxicity in living organisms. Similarly, our water resources, such as rivers, lakes, and the sea, are contaminated with many chemicals, nanomaterials, and plastic waste. We have developed simple, sustainable polymers and technologies for the removal of a diverse range of pollutants from water. The talk will focus on different material synthesis strategies for developing functional materials and their applications in dealing with complex environmental challenges.

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Advanced Polymeric Materials and Their Technologies & Products for Defence Applications

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In general, polymers are very versatile and fascinating materials that are widely used to develop advanced technologies and products for various applications, including defence applications. High-performance polymers and composites, being lightweight materials and having high specific strength, processing flexibility and corrosion-resistant properties, are preferred materials for their engineering and structural applications such as in aero-structures, spacecrafts, missile and naval systems, armour applications and other defence systems, in addition to their civilian applications. Again, smart, self-healing and multifunctional polymers are important classes of innovative materials that are being used in cutting-edge technologies in all such above applications and are now crucial components for the sustainable development of any technology and the creation of a 'smart world'.

We, at DMSRDE (DRDO), are nurturing various polymeric materials, including high-performance polymers, composites, rubbers, fibres, smart, self-healing and functional polymers for different defence applications. This presentation would become a glimpse of our research findings of such polymeric materials and their applications in various defence systems, such as (i) high performance PEEK polymeric components, (ii) phthalonitrile resin and its composites, (ii) rubber and thermoplastic PTFE based seals and gaskets, (iii) rubber based nuclear shielding pads, (iv) high-performance fibers and their polymer composite structures, and (iv) functional innovative polymeric materials for cutting-edged technologies including smart and self-healing and stealth technologies.

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Design and Application of Natural Protein-based Biopolymer: Exploring Structure, Biofabrication, and Multifunctionality

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Biofabricated natural biomaterial scaffolds are essential in regenerative medicine and disease modelling applications. For example, natural silk protein fibroin is used as a biomaterial and is studied as an extracellular matrix mimic. The material possesses biocompatibility, minimal immune response, tunable biodegradability, and good mechanical strength. Silk materials can be fabricated in various formats, such as 3D scaffolds, films, sponges, nanoparticles, and nanofibers. The scaffolds allow for the creation of structures that can provide physical support for cells and tissues and provide space for new tissue growth and regeneration due to biodegradation. The matrices can be used for cell growth and differentiation, and their properties can be modified to resemble the native extracellular matrix environment better and be tailored to meet specific tissue regeneration needs. These properties make it suitable for tissue engineering and regenerative medicine applications, including 3D in vitro disease modelling. 3D cell culture platforms provide more comprehensive information regarding cancer pathophysiology, including cancer proliferation, progression, metastasis, and drug screening and treatments. The matrices are suitable for obtaining details of cancer architecture. The models should exhibit consistency and an appropriate microenvironment for the screening of drugs. The presentation will detail the biofabrication of various matrices for normal, disease and coculture of different cells, and will also cover stem cell differentiations. It will also discuss applications in tissue engineering and regenerative medicine, as well as 3D in vitro tissue-engineered cancer disease models and drug screening.

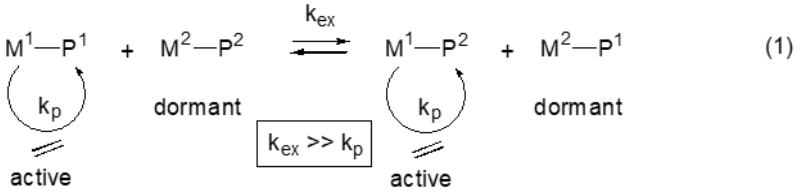
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Catalysed Chain Growth: from Curiosity to Applications

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A convenient method to generate polymer chains with reactive chain ends is via reversible coordinative chain transfer polymerisation. This method uses a polymerisation catalyst (M^1) in combination with a chain transfer agent (M^2) and makes use of a very fast and reversible exchange of the growing polymer chains (P^1 and P^2) between the catalyst and a transfer agent (see Eq. 1). A range of transition metal catalysts can be used, whereby transfer agents are typically based on main group metals such as trialkyl aluminium, dialkyl magnesium or dialkyl zinc reagents.[1]



A specific case where all metal alkyl chains are equally engaged in reversible coordinative chain transfer polymerisation is termed Catalysed Chain Growth (CCG).[2] CCG leads to a controlled growth of all alkyl chains on the main group metal, for example, Zn, and results in Zn(PE)n with a Poisson distribution of PE chain lengths.[3] Hydrolysis (or protonolysis with HX) will generate linear alkanes PE-H and $Zn(OH)_2$ (or ZnX_2). The high reactivity of Zn-C bonds can also be exploited to generate end-functionalised polyethylenes PE-X, where X is for example a halide, hydroxide, sulfide or amine functionality.[4]

End-functionalised PE-X chains can be further derivatised and subsequently be incorporated into a polymer matrix through extrusion. This method enables the preparation of PE materials with specific functionalities, for example anti-microbial properties. Alkylation of polar polymers such as cellulose or lignin with PE-X enables their incorporation to prepare composite materials with excellent dispersion.[5]

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Design and Evaluation of Bio-Based Industrial Materials through Experimental and Statistical Data Integration

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Wood, together with its principal polymeric constituents-cellulose and lignin-and related materials such as paper, has been investigated in our group from a polymer-science perspective to develop and evaluate bio-based industrial materials. Practical issues in bio-based industrial materials-such as the deterioration of wood coatings and the dispersion of inorganic fillers in paper coatings-appear highly applied, but are closely related to fundamental problems of molecular degradation and interfacial interactions in polymer science. Nevertheless, these topics still rely heavily on empirical knowledge, and systematic guidelines for evaluation and design remain limited. This presentation introduces several recent attempts to connect experimentally accessible data with statistical analyses to advance the design and assessment of bio-based industrial materials.

(1) Diagnosis of wood-coating deterioration [1,2]: Acrylic, acrylic-urethane, fluorinated, and alkyd resin coatings were subjected to accelerated weathering and outdoor exposure at two sites. Attenuated total-reflection Fourier-transform infrared (ATR-FTIR) spectra were analyzed using partial least-squares (PLS) regression combined with a genetic-algorithm-based wavenumber-selection procedure. Characteristic spectral regions responsible for degradation were successfully identified, and the resulting predictive model quantified latent deterioration with high accuracy across resin systems and climates. When implemented in portable devices, this framework enables scientific maintenance of coated wood surfaces beyond conventional visual inspection.

(2) Evaluation of nanoclay dispersibility [3]: Natural, synthetic, and organo-modified clays were dispersed in various solvents, and solvent–particle interactions were quantified via NMR relaxation-time measurements. Hansen solubility parameters (HSPs) were calculated to estimate the dispersibility and rank solvent suitability for each clay. The combination of NMR relaxation and HSP analysis allowed rapid comparison of dispersibility even in sedimentation-prone systems, facilitating the selection of environmentally benign solvents and contributing to standardized formulation of dispersion systems.

(3) Application to paper coating [4,5]: Using solvents selected by HSP analysis, poly(butylene adipate-co-terephthalate) (PBAT)/hectorite nanocomposites were prepared and coated onto kraft paper. The coated papers were evaluated for mechanical strength, water resistance, and gas-barrier performance. The PBAT/hectorite coatings reduced oxygen transmission by 58 % and water-vapor transmission by 48 %, exhibiting excellent water and oil resistance.

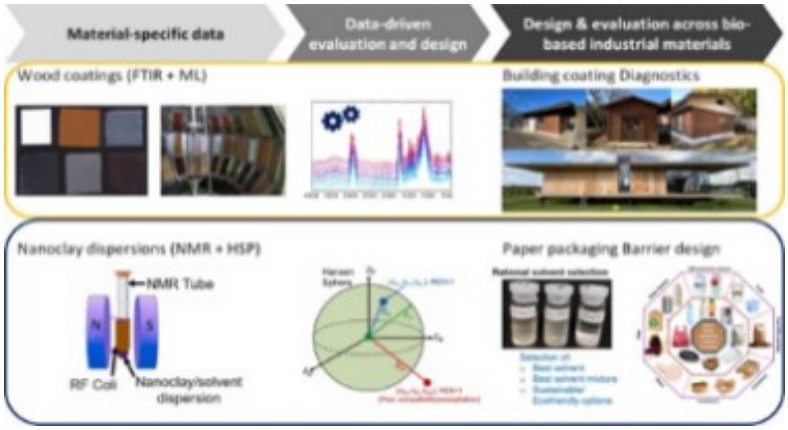


Figure: From material-specific data to data-driven analysis and design of bio-based industrial materials.

Keywords: bio-based materials; polymer coatings; solubility parameters; spectroscopy; machine learning

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Polymeric Filter Media with Antibacterial Properties from Recycled Polyethylene Terephthalate Bottles and Reclaimed Facemasks

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This study presents a method for the development of high-performance filter media with antibacterial properties from the nanofibers of recycled polyethylene tersephthalate (PET), electrospun on used facemasks and sets the stage for generating high-performance filter media from recycled feedstocks with potential applications in personal protective equipment. The electrospinning solutions of PET contain 10 to 25 wt% of PET dissolved in a solvent mixture of hexafluoroisopropanol and dichloromethane. The electrospun nanofibers obtained from 10 wt% PET solution demonstrate the best performance in filtering airborne nanoparticles with a filtration efficiency of 87 ± 2.9 % and a quality factor of 1.31 per 2.54 cm of water pressure drop across the media. The study also evaluates the influence of benzalkonium chloride (BAC) salt initially dissolved in PET solution at a concentration of 10-50 wt% with respect to the PET content on nanofiber diameter and filtration efficiency. The presence of BAC leads to fiber diameter reduction, narrowing of fiber diameter distribution, and production of bead-free, smooth fibers. The filter media produced with BAC show filtration efficiency of 98 ± 0.8% and a quality factor of 1.77 per 2.54 cm of water pressure drop, that exceed the filtration performance of a commercial N95 mask. The study establishes the antibacterial attributes of BAC, e.g., nanofibers containing BAC inhibit the growth of the gram-negative bacteria, Pseudomonas aeruginosa and the gram-positive bacteria, Staphylococcus aureus. The nanofiber mat, with 20 wt% or greater content of BAC, releases enough BAC in the aqueous media to inhibit the growth of both S. aureus and P. aeruginosa.

Keywords: antibacterial; electrospinning; recycled facemasks; high efficiency filtration; PET bottles.

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Sustainable Polymer Coatings Enabling a Low-Carbon Future

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Polymers and polymer composites play a vital role in modern society, with applications spanning personal care, automotive, construction, and low-carbon energy technologies-including wind turbines, solar panels, solid polymer electrolytes for lithium-ion batteries, and membranes for electrolysers and fuel cells. Notably, polymers used as paints and coatings are especially important for promoting sustainability and driving decarbonization efforts.

In this presentation, we will provide an overview of our research on the synthesis of polymers, polymer particles, and their coating formulations for decarbonization-related applications. First, we will highlight our work on CO_2-derived non-isocyanate polyurethanes (NIPUs) for diverse uses, including industrial and self-healing coatings[1-2]. Next, we will discuss how polymer particle morphology—such as polymer-encapsulated TiO_2 pigments[3] and fluoropolymer core–shell nanoparticles[4] enhances solar reflectivity and durability in cool coatings, contributing to building cooling and mitigation of the urban heat island (UHI) effect. Finally, we will present preliminary results on polymers[5] with low hydrogen permeability, designed for coatings that may resist hydrogen embrittlement, a key challenge for the hydrogen economy. Upon success, these coatings could be applied to critical infrastructure, including metal pipelines and storage tanks for hydrogen transport, distribution, and storage.

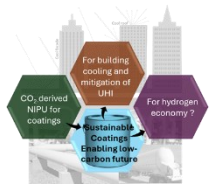


Figure 1: Different sustainable polymer coatings for low-carbon future.

Keywords: sustainable coatings, self-healing, cool coatings, urban heat island and hydrogen embrittlement

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Design of Drug Delivery Vehicles for Disease Control

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A variety of polymeric molecules have been developed for sustained drug release by controlling hydrophilic-hydrophobic balance, grafting, copolymerization, core-shell through photo-polymerization or nanoparticle insertion for effective healthcare. Up to third generations of molecules are designed through urethane linkages using a small spacer to create a large hydrophilic core, which is covered with hydrophobic layers of polyurethane through grafting to maintain the hydrophilic-hydrophobic balance of the whole superstructure. Core photopolymer and subsequent graft polymerization (core shell), leading to slow release of drug has been developed. Drug release becomes sustained from the complex structure following the non-Fickian diffusion process, resulting massive cancer cell killing as compared to a meagre killing rate from the pure drug arising from its burst release. Drug embedded polymeric network is inoculated in injectable hydrogel and is placed in subcutaneous, below the tumor site, which has the ability to completely heal the melanoma. Further, cyclodextrin has been copolymerized with polyurethane for controlled release of insulin for better diabetic control. Bone regeneration has been shown to be effective from the slow release active ingredients from biodegradable polymer. Similarly, ayurvedic drug has been processed using polymer network for wound healing and thereby shown to be effective in clinical studies involving large animal. No side effect is observed, as opposed to conventional/control system, due to sustained drug release from the polymer network as evident from histopathological studies of sensitive body organs and biochemical parameters. Thus, new design of vehicle heals the melanoma, bone regeneration, better diabetic control and wound healing by enhancing the bioavailability of the drug.

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Porous Polymer-Gel Hybrid Scaffolds for Tissue Engineering

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Abstract: Tissue engineering is a multidisciplinary field that combines principles of engineering, biology, and material science to create functional and viable biological tissues for medical applications. It involves the use of scaffolds, cells, and bioactive molecules to regenerate, repair, or replace damaged or diseased tissues in the human body. The ultimate goal of tissue engineering is to develop innovative strategies that can restore normal tissue function, offering potential solutions for a wide range of medical conditions, from organ failure to traumatic injuries. This cutting-edge field holds great promise for revolutionizing regenerative medicine and improving the quality of life for patients in need of tissue replacement therapies.

In the presentation, I will discuss our recent work on the development of composite scaffolds containing porous polymers and hydrogels, for tissue engineering applications. The gel phase consists of gelatin methacrylate (GelMA)[1], which has emerged in recent years as the most commonly used bio-ink in 3D bioprinting due to its ease of production, suitable mechanical properties and the suitable microenvironment it creates for cell expansion and function. GelMA is combined with a variety of porous polymer scaffolds[2], including melt electrowritten polycaprolactone meshes and porous polymer granular scaffolds[3], to create scaffolds for use as 3D skin models and as injectable bone regeneration scaffolds. Other hybrid systems consist of photocurable resins that can be 3D printed or moulded into different shapes, which when combined with sacrificial 3D printed lattices result in scaffolds of hierarchical porosity for bone regeneration.

Keywords: porous polymers, scaffolds, bioprinting, hybrid materials.

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Topochemistry for solving challenges in polymer synthesis

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Topochemical reactions, the reaction between pre-organized reacting motifs in the crystal lattice, are attractive as they do not require solvents, catalysts and other special reaction conditions for the reaction and provide products in pure form. Also such reactions provide basic understanding about mechanistic and geometrical details about a reaction.[1] We have employed thermal Topochemical Azide–Alkyne Cycloaddition (TAAC), Topochemical Ene-Azide Cycloaddition (TEAC) and Topochemical Diels-Alder Cycloaddition (TDAC) reactions to synthesize various biopolymer mimics. We have exploited hydrogen bonding for the self-assembly of monomers in solid to pre-organize the reacting motifs. Lattice controlled polymerization/oligomerization reaction of such self-assembled (pre-organized) monomers gave various biopolymer mimics. By applying this methodology, we have topochemically synthesized monodisperse glycopolymers, oligosaccharide mimics, DNA analogs and polypeptides.[2-14] In this talk, I will demonstrate the use of topochemical polymerization in the synthesis of ladder polymers, 2D polymers, stereocomplex, polymer-polymorphs etc.

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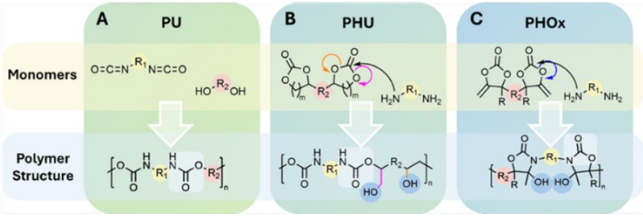
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Non-isocyanate polyurethane biomaterials: from synthesis towards 3D-printed medical devices

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Segmented polyurethanes (PUs) exhibit remarkable mechanical performances and proven in vivo biocompatibility, so they are key biomaterials. Industrially produced from highly toxic isocyanate precursors, which causes serious environmental and health concerns, the exploration of greener and safer alternatives to produce PUs has become imperative and has triggered the emergence of a new family of PUs called non-isocyanate polyurethanes (NIPUs). Among the latter, those produced from bifunctional cyclic carbonates and diamines give NIPUs exhibiting unprecedented molecular structures, namely, poly(hydroxy-urethane)s (PHUs) or poly(hydroxy-oxazolidone)s (PHOxs). These NIPUs structures are differing from those of isocyanate based PUs, as they bear additional hydroxyl groups, and in case of PHOx, the urethane is in addition part of a ring structure as illustrated in the figure below. Therefore, NIPUs exhibit specific properties [1].



We have explored the impact of these structural differences on the properties of NIPUs, while highlighting their potential to design biomaterials focusing on the development and the characterization of various NIPUs (both PHUs and PHOxs) for applications in the cardiovascular field. Different formulations have been studied mainly targeting implantable elastomers [2-4]. A particular attention has been also paid to the printability of these materials to produce 3D printed implants which are customizable according to patients. The biocompatibility and hemocompatibility have been also assessed by means of a series of biological tests to ensure their non-toxicity and compatibility with the cardiovascular system.

Keywords: Non-isocyanate polyurethane, biomaterials, 3D-printing.

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AI-Driven Frameworks for Generative and Discriminative Material Design

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Designing novel crystal materials with targeted chemical properties remains a central challenge in materials science. Traditional approaches using Density Functional Theory (DFT) are effective but computationally expensive. To address this, we develop a suite of AI-based frameworks that advance both discriminative and generative tasks in material design.

For property prediction, CrysXPP (NPJ Comp. Mat. 2022) introduces an unsupervised autoencoder to learn crystal representations from unlabeled data; CrysGNN (AAAI 2023) employs self-supervised pretraining for transferable crystal property prediction; and CrysMMNet (UAI 2023) integrates graph and textual modalities to enhance predictive accuracy.

For structure generation, TGDMat (ICLR 2025) presents a text-guided diffusion model that jointly generates lattice parameters, atom types, and coordinates, while CrysLLMGen (NeurIPS 2025) synergizes large language models and diffusion models for stable, compositionally valid, and novel crystal generation under user-defined constraints.

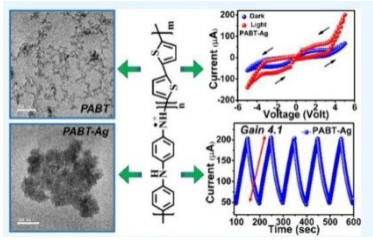
Together, these efforts establish a scalable AI paradigm that unifies structure generation and property prediction, accelerating the discovery of next-generation functional materials.

Opto-electronic properties of Polyaniline-block/ran -Polythiophene copolymer with in situ Growth of Silver Nanocluster: Effect of dopant

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Recently great deal of research is focused to develop hybrid polymeric materials for different optoelectronic applications. Here, we have synthesised dinonyl disulphonic acid (DNNSA) doped polyaniline, (PD), polyaniline-block-polythiophene (PANI-b-PT, PABT) and polyaniline-ran-polythiophene (PANI-ran-PT PART), camphor sulphonic acid (CSA) doped PBT and PRT by emulsion polymerization. When AgNO3 is added to the reaction medium, in PD-Ag AgNPS are produced1 but in PABT/PART-Ag system Ag-nanoclusters (AgNCs) are formed and stabilized by sulphur atom of PT chain via soft acid-base interaction.2 PABT/PART systems exhibit fibrillar network morphology, but, PABT-Ag and in PART-Ag systems exhibit sheet morphology with tiny nanoparticles of raspberry architecture. Particle size from HRTEM show nanocluster sizes (~3.5 nm) comprised of 10 Ag atoms for both PABT-Ag and PART-Ag systems. The absorption peaks of PART showed 5-8 nm blue shift from PABT for pπ−dπ interaction. PART exhibits ~3.5 times higher current than PABT and on irradiation with white light, photocurrent increases 2.5-3 times in the AgNC coupled systems. The photocurrent growth in PABT-Ag and PART-Ag systems growths are faster than PABT and PART systems suggesting AgNCs play important role in enhancing photocurrent.



Microscopic study of CSA-doped PBT and PRT system3 also exhibits fibrillar network morphology with Ag–NC formation of average sizes 3.33nm and 3.07nm, respectively. The mechanism of formation of PBT, PRT and AgNCs is elucidated from reduction potential values obtained from cyclic voltammetry. dc–conductivity values of PBP, PBP–Ag, PRP and PRP–Ag are 2-4 mS/cm decreasing with increasing temperature indicating metallic nature. I-V plot also indicates metallic nature with higher slope for PBP–Ag and PRP–Ag than pure polymers. On illumination, similar I–V nature with ~2.5 times higher photocurrent is noticed than dark at +5V. Photo–switching experiment shows stable on–off cycle with lower photocurrent gain (Ion/Ioff) of PBP-Ag and PRP-Ag(1.07, 1.05) than pure samples(3.06, 2.78). The random copolymer and its nanocomposites exhibit ~2 times higher current than block copolymer for pπ−dπ interaction. The band gap values are lower for PRP–Ag(2.00 eV) and PBP–Ag(2.10 eV) than PRP (2.20 eV) and PBP (2.28 eV) indicating stabilization of PANI/PT excitons on AgNCs, also supported from DFT calculations. Impedance results indicate lower charge transfer resistance of PBP–Ag(2.3 Ω) and PRP–Ag(1.3 Ω) than PBP(10.9 Ω) and PRP(9.3 Ω) whereas, enhanced capacitance occurs in former systems (30 and 40 mF) than later systems (7.1 and 8.5 mF). A comparison of the optoelectronic data with DNNDSA doped PABT and PART systems indicate a 400-500 times hike in dc–conductivity, 200 to 600 times hike of dark current and nearly 100-200 times higher photocurrent. The hike of opto-

electronic data in CSA doped polymers is for stronger doping of PANI by CSA and also for its molecular recognition effect.

Keywords: Emulsion polymerization, PANI-PT copolymers, Ag-nanocluster, I-V property, Photocurrent property.

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Climate Challenges and Technological Transformation in the Tyre and Rubber Industry

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The global rubber and tire industry faces mounting challenges from climate change, resource constraints, and evolving regulatory pressures. Climate variability increasingly disrupts the cultivation of *Hevea brasiliensis*, the primary source of natural rubber, through droughts, floods, and disease outbreaks. These disruptions threaten supply chain stability for a raw material that currently lacks a fully sustainable alternative. Simultaneously, the production of synthetic rubber remains energy-intensive and heavily dependent on fossil fuels, contributing to significant greenhouse gas (GHG) emissions and microplastic pollution. Governments are responding with stricter environmental policies—such as the European Union's Emission Trading System and Extended Producer Responsibility (EPR) programs—driving up compliance costs and necessitating greener practices.

Energy consumption poses another critical challenge, particularly during the vulcanization process, which requires high temperatures and pressures. Additionally, the industry must address the environmental burden of millions of end-of-life tires (ELTs) generated annually, which resist natural degradation and release toxic compounds when improperly disposed of. Market volatility in both natural and synthetic rubber further complicates cost management and production planning.

In response, the sector is leveraging emerging technologies to build resilience, enhance efficiency, and accelerate the transition toward sustainability. Bio-based materials derived from sources such as dandelions, guayule, rice husk silica, and vegetable oils are reducing reliance on petroleum-based inputs while lowering the carbon footprint of tire manufacturing. Advanced recycling technologies—such as pyrolysis and devulcanization—are creating closed-loop systems by recovering valuable resources like carbon black, oil, and steel from ELTs.

Digitalization and smart manufacturing are transforming production efficiency through automation, artificial intelligence, and real-time monitoring, while lifecycle assessment (LCA) tools enable data-driven sustainability management. Product innovations such as low-rolling-resistance (LRR) tires, incorporating nanotechnology and advanced fillers, are improving vehicle energy efficiency and significantly reducing emissions during use—the most carbon-intensive phase of a tire's life. Moreover, smart tire technologies with embedded sensors enhance safety, extend tire lifespan, and minimize waste through optimized maintenance.

Finally, the industry is exploring alternative energy solutions, including hydrogen-based steam generation and the integration of renewable (solar/wind/hydro) or clean electricity in production facilities. Together, these innovations represent a paradigm shift from a resource-intensive linear model to a more sustainable, circular, low-carbon, and digitally optimized industry framework.

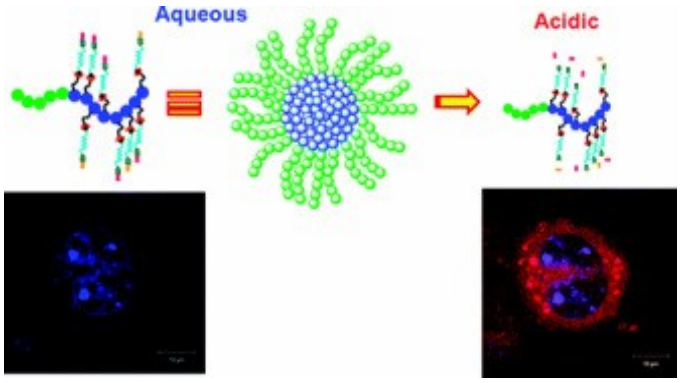
The convergence of sustainable materials, advanced recycling, smart technologies, and clean energy positions the rubber and tyre industry at the forefront of industrial transformation. By aligning innovation with environmental stewardship, the sector can mitigate climate risks, ensure long-term resource security, and contribute meaningfully to global decarbonization goals. In the presentation all the above points will be discussed.

Designing Functional Polymers for Therapeutic Applications

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Theranostic-based nanomedicine plays a crucial role in cancer therapy. This is due to having the capability to combine both treatment and diagnosis in a single system. A new class of metal-ligand-based nanocarrier in a polymer backbone has been designed as a theranostic system. An NMR experiment is performed at room temperature to prove the MRI capabilities of copolymer nano-aggregates. Cell viability studies suggest the biocompatibility of the copolymer. Flow cytometry and epi-fluorescence microscope experiments demonstrate the dual-imaging ability of the newly designed copolymer. The much higher relaxivity ratio (r_2/r_1) of the present method establishes the superiority of our system as one of the best contrast agents known to magnetic resonance imaging practitioners.



Figures 1 - Stimuli-responsive functional polymers.

Keywords*:* Functional polymers, stimuli-responsive, self-assembly, biodegradable, living polymerization

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Sustainable Phenolic Resins: Evaluating Lignin-Based Alternatives Through LCA and Radiocarbon Analysis for Industrial Applications

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Sustainable materials innovation is central to achieving carbon neutrality across industrial value chains. Reducing CO_2 emissions from industrial operations and usage of regionally available raw materials are critical strategies to address climate change and support the global goal of limiting temperature rise to 1.5°C[3]. This paper outlines ours approach towards achieving net-zero emissions by 2050. The scope 3 emission such as raw materials and transportation occupies major portion of groups emission worldwide. Responsible sourcing and supplier engagement are ways to build sustainable culture across industrial ecosystem. Substituting fossil derived phenolic resin (Low cost & superior performance)1with biobased alternatives such as lignin derived phenolic resins represents a major step towards decarbonization of thermosets used in insulations and abrasives product lines. The lignin, an abundant by product of paper and pulp industry[2], offers an aromatic structure for replacing partial or complete replacement of phenol in phenol formaldehyde resin. The advent of biorefineries for processing lignocellulosic biomass in India for producing lignin makes this practically possible. This work evaluates the life cycle analysis, technical performance and implementation potential of lignin-based phenolic resins within Saint-Gobain product line. To substantiate the statement, C14 Analysis (radiocarbon dating) and rheological analysis of lignin-based PF Resin (LPF) and PF Resin was carried out. The Analysis indicates 20% lignin incorporated LPF Resin found to have biogenic carbon content of 16% and emission reduction of 12% in terms of CO_2 equivalent. Also, the LPF Resin shows longer storage stability of 4X than PF resin and same cure initiation temperature as PF Resin, brings in added sustainability to the resin by reducing the waste during storage and avoids additional energy during processing.

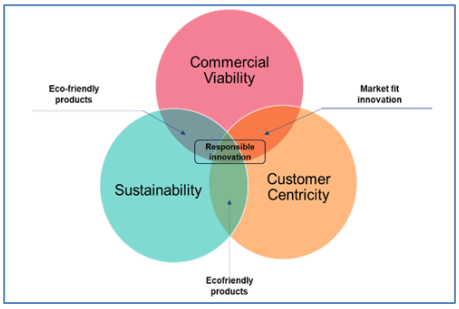


Figure 1: Responsible innovation Venn diagram.

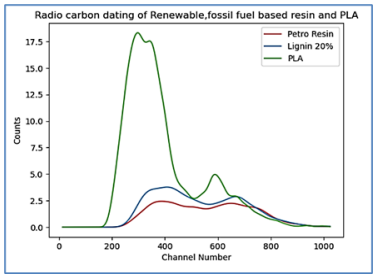


Figure 2: C14 Analysis results

Keywords: Lignin-based PF resin (LPF), Life Cycle Assessment (LCA), circular economy, carbon footprint, C14 analysis,

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Hierarchically Architected Semicrystalline Polymer Aerogels for Multifunctional Applications

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Polymer aerogels have attracted significant attention in recent years due to their exceptional characteristics, including high porosity, low density, low dielectric constant, low thermal conductivity, and large specific surface area.1-5 The growing demand for polymer-based aerogels with superior multifunctional properties has expanded their potential applications in packaging, thermal and acoustic insulation, filtration, adsorption, electromagnetic interference (EMI) shielding, water harvesting, and energy harvesting. In this talk, I will present strategies for tailoring the crystalline forms of semicrystalline polymer-based aerogels, focusing on materials such as nylon 11,1,2 poly(vinylidene fluoride) (PVDF),3,4 and poly(3-hydroxybutyrate) (PHB)5. Particular emphasis will be given to the fabrication of both isotropic and anisotropic polymer aerogels, including hybrid aerogels incorporating MXenes. For the first time, we have demonstrated the orientation of polymer crystals along the freezing direction in nylon 11 aerogels1,2, as well as the alignment of MXene nanosheets at the pore boundaries in PVDF/MXene anisotropic aerogels3,4. These oriented structures result in anisotropic properties, with distinct performance differences along and perpendicular to the freezing direction. Finally, I will discuss the multifunctional applications of these aerogels, highlighting their performance in thermal insulation, acoustic insulation, EMI shielding, water harvesting, and energy harvesting.[1-5]

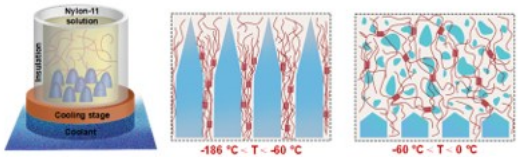


Figure. Experimental setup for unidirectional freezing and schematic showing the directional freezing process of nylon-11 solution in the temperature range of -186 °C to -60 °C and -60 °C to 0 °C.

Keywords: Semicrystalline polymers, thermoreversible gels, crystallization, aerogels

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Waste Plastic Depolymerization and Upcycling

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India produces approximately 20 million tons of plastic every year, yet only a meagre 15-20% of this plastic is recycled, presenting a significant challenge to plastic waste management. The remaining waste predominantly ends up into landfills or leaks into water bodies, causing severe environmental pollution. Thus, the current linear model of plastic utilization, that is, take, make, use, and throw is not sustainable. To address this critical issue, we have undertaken in-depth investigation about plastic depolymerization and upcycling. A brief overview of segregation, plastic to fuel and downstream processing will be presented. The second part of the talk will deal with depolymerization of waste plastic to value added long-chain alkenes. The PCP-iridium complex Cat.1 (Fig. 1) catalyzes the dehydrogenation of commercial, as well as, postconsumer polyethylene waste to produce dehydrogenated polyethylene (DHP). The DHP was subjected to an ethylene cross-metathesis reaction in the presence of suitable catalysts. Through meticulous optimization of reaction parameters, 63% selectivity toward dodecene was achieved. The practical significance of our method has been demonstrated by subjecting the plastic waste to dehydrogenation followed by ethylene metathesis to produce dodecene as a major product, together with long-chain alkenes. [1,2]

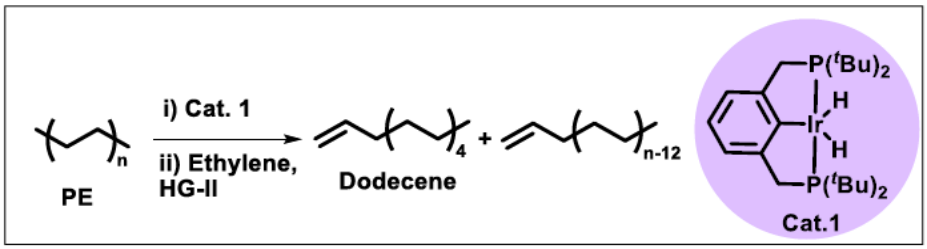


Figure 1: Schematic representation of waste plastic depolymerization to dodecene and long-chain alkenes

Keywords: Waste Plastic; Polyethylene; Depolymerization; Upcycling; Dodecene

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Contribution of Polymeric materials: To get sustainable materials via circular economy in construction chain value and greener planet

Jagabandhu Kole

The construction value chain is a strategic framework aimed at maximizing resource efficiency and minimizing waste across all stages of construction activities. Rapid industrialization over recent decades has undoubtedly improved human living standards; however, it has also intensified resource extraction and accelerated waste generation from manufacturing and industrial operations. In the past, limited attention was given to circular economy principles, zero-waste technologies, and long-term environmental impacts. As a result, issues such as greenhouse gas emissions and their contribution to climate change have become critical and demand immediate attention, as they are affecting the existence of humanity on the Earth. This scenario highlights the necessity for wide-ranging and transformative changes within the construction value chain, particularly the development and adoption of alternative materials.

Simultaneously, global demand for construction materials continues to grow due to rapid population growth and expanding economies that require new commercial, residential, and public infrastructure. This growth places additional pressure on industries to increase production of primary materials, many of which have high embodied carbon and substantially contribute to global CO_2 emissions. As a result, decarbonizing the cement industry along with other energy-intensive sectors has become a global priority. Developing sustainable materials using industrial waste and disposable by-products to address disposal challenges while ensuring environmental safety as well as reducing CO_2 emission has therefore become a central focus for researchers and scientists.

Since its inception in 2008, JSW Cement has consistently practiced the philosophy of the circular economy. To promote the use of supplementary cementitious materials (SCMs) in concrete production, the company continues to develop a range of performance-enhancing and functional polymer-based materials. These polymers play a crucial role in activating SCMs and enabling alternatives to naturally excavated cementitious resources. JSW Cement is rigorously engaged in advancing polymeric applications within the cement manufacturing process to produce durable, low-carbon cement and contribute meaningfully to sustainable construction.

Lately, Durable Low Carbon Cement (DLCC), an ultra–low-carbon cement, has been developed by inter-grinding ground granulated blast furnace slag (GGBS) with calcium sulphate and 5% cement clinker. However, the very low clinker content leads to major challenges in workability, slump retention for high-rise construction, and early-age strength development. To address these issues, a specific type of poly-carboxylic ether admixture has been used.

Similarly, advancements have been made in the development of geo-polymer cement. Geo-polymers are ceramic-like ***inorganic polymers*** produced at low temperatures, generally below 100 °C. They consist of chains or networks of mineral molecules linked by covalent bonds. However, geo-polymer cement with 0% clinker content has shown workability issues and inadequate slump retention for high-rise construction practices. Therefore, a new generation of admixtures is required to overcome these challenges and which has been addressed by synthesizing a suitable polymer in- house R & D of JSW Cement Ltd.

Sustainable Polymers for Commodity, Engineering and Biomedical Applications

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This presentation highlights the use of available bio-resources for value added sustainable polymeric products for Engineering, Commodity and Biomadical Applications. Biopolymers can be extracted from renewable feedstock such as plants, marine animals, insects, etc. It is noteworthy to mention that so far biopolymers extracted from these sources have limited applications in large scale plastic production. Among the available bio-based plastics, polylactic acid (PLA), poly (caprolactone), Polyhydroxyalkanoates, have made its own place due to its biodegradability and have a potential to replace some of the conventional fossil based plastics. It is noteworthy to mention that properties such as melting point, stiffness, heat stability temperature and gas barrier properties limit its use in high temperature commodity and engineering applications. In relation with PLA, such limitations can be overcome by developing new class of high molecular weight stereocomplex PLA (sc-PLA). In this context, sc/sb-PLA and its sc/sb-PLA-bionanocomposites by using different biobased nanofillers which includes cellulose nanocrystals, silk nanocrystals, modified chitosan, etc. The formation of stereocomplex crystallites is confirmed by the XRD analysis. The melting point of the composite is increased even higher than 225°C which suggests the formation of stereocomplex crystallites and the Heat Deflection temperature is enhanced upto ~140°C at optimum bionanofiller loading. Due to the presence of various bionanofillers, ultimate tensile strength is enhanced significantly. Based on the studies, it is concluded that bionanofillers are good candidates for enhancing the stereocomplexation in the PLA. In this talk, fabrication strategies for synthesis of stereocomplex-PLA-bionanocomposites and evaluation of their properties along with possible applications will be discussed. This talk will also focus on fabrication of bionano-fillers, edible food packaging, processing of bionanocomposites caste films, injection molded products and 3D printing for biomedical and also its uses in energy applications. This presentation will also be focused towards utilization of other bio-based plastics and their formulations in the area of agriculture, food packaging, energy harvesting, biocatalysis, water purification, orthopedics, self-cleaning Fabrics. Further, translational research at IIT Guwahati on sustainable Plastics based products will also be highlighted during the presentation.

Keywords: Bioplastics; Polymer processing, Composting, large-scale production of bioplastics.

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From Polymerizable Ionic Liquids to Poly(ionic liquid)s: Exploring Structure-Property Relationships and Applications

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Advanced poly(ionic liquids) (PILs) represents an important new class of ionic polymeric material, containing functional ionic liquid species in each of its repeating unit as versatile building blocks bearing unique properties. In this context, our research primarily focuses on the design and synthesis of diverse ionic liquid monomers (ILMs) and zwitterionic ionic liquid monomers (ZILs) and subsequently polymerized them via RAFT and CRP techniques. Furthermore, the controlled cationic polymerization of ethyl vinyl sulfide (EVS) produces PEVS, which is functionalized with long-chain 1-bromoalkanes and 2-nitrobenzyl bromide to yield semicrystalline and photo-responsive PILs, respectively. The discussion focuses on the synthesis of a series of ionic polymers, including phosphonium- and imidazolium-based poly(ionic liquid)s (PILs), poly(zwitterionic ionic liquid)s, and their copolymers, as well as investigations of their thermoresponsive behavior arising from electrostatic ionic bridging interactions in the presence of added anions. The resulting PZILs also display pH- and ion-responsiveness along with a unique UCST-type phase behavior in aqueous media. This followed by the discussion on the transformation of aqueous transparent solutions of PILs/PZILs into turbid suspensions due to the formation of insoluble hierarchical nanoaggregates (NAs) of various morphologies such as small spheres, large spheres, flower-like, dendrite-shaped, and dendritic fibril-like depending upon the solution pH and PILs' structures. A cross-linked hydrogel system containing phosphonium/imidazolium PILs/PZILs with both halide ion- and thermo-responsiveness (UCST-type) will also be presented. PILs and PZILs (below their isoelectric point) behave as cationic PILs and can effectively debundle multiwalled carbon nanotubes (MWCNTs), forming stimuli-responsive nanocomposite dispersions. Furthermore, PZILs exhibit antiprotein-fouling properties, demonstrating their potential as antifouling materials. In addition, we investigate how the thermal and crystalline properties of long alkyl-chain PILs are dictated by alkyl chain length and counter-anion identity. The long alkyl-chain bromide-based PILs, in less polar solvents such as chloroform, undergo UCST-type phase transitions and spontaneously self-assemble into vesicles capable of encapsulating dyes, highlighting their promise in targeted delivery applications.

Keywords: Ionic liquid monomers; Poly(ionic liquid)s, Stimuli-responsiveness; Self-assembly; Antifouling behaviors; Semicrystallinity.

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NextGen Adhesives and Sealants based on Hybrid and Sustainable Materials

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Adhesives and sealants are an integral part of our daily life: Starting from our early days using school stationary glues and sticking small items at home to industrial applications like packaging, mattress assembly, paper converting adhesives, and structural adhesives for highly demanding automotive, construction and aerospace industries.

At Pidilite, we offer adhesives and sealants products with application focusing on wood working and furniture applications in the retail segment; Waterproofing, tile adhesives and sealants for construction industries; Household and general-purpose adhesives for consumer market segment and various industrial adhesives, coatings, and sealants for automotive, packaging, footwear, and textile segments.

As a responsible leader in driving sustainability, we have created products that qualify green building requirements and are focusing on integrating bio-based products, making our products and packaging environment friendly. We have also developed our new adhesives, sealant and coating products by combining the organic, inorganic and nanomaterials to produce differentiating products with unique value proposition for our customers.

Innovation by collaboration is our key to success in the market. We want to move away from 'not invented here' syndrome and actively partner with academia, start-ups and suppliers to develop new sustainable products and processes that can help us develop products faster and scale them quickly to have a first mover advantage.

Keywords: Adhesive, Sealant, Coating, Sustainability

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Environment and regulation related challenges in tyre industries

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There is a growing global demand for the adoption of more sustainable materials in tire manufacturing, driven by both regulatory pressure and environmental expectations. New regulations targeting the reduction of tire road-wear particles are reshaping material selection and compounding strategies. The industry is moving toward greater use of unified natural rubber streams and is actively pursuing the elimination of legacy chemicals such as the antioxidants 6PPD and 7PPD, as well as the accelerator DPG, due to environmental and toxicological concerns. In parallel, digital tracking technologies such as RFID are being implemented to enable improved tire traceability, performance monitoring, and lifetime assessment. These changes align with the broader framework of Extended Producer Responsibility (EPR), which emphasizes accountability for the environmental impact of tires throughout their lifecycle.

Keywords: Tyre; sustainability; extended producer responsibility

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INVITED LECTURE

Tailored Biopolymeric Materials: From Molecular Design to Biomedical Use

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Functionalized biopolymers are promising materials for biomedical use due to their biocompatibility, tunable properties, and ability to mimic natural tissues. In authors' laboratory, several new biopolymeric materials have been developed1-4, which show significant potential for use in targeted drug delivery, injectable therapies, and hemostats to control bleeding.
The biopolymeric hydrogels have good gel strength and shear stability, making them effective under real biological conditions. Their mechanical and structural features can be fine-tuned during synthesis to fit specific medical needs.
This talk will briefly cover how these biopolymeric materials are designed and made, focusing on how their structure relates to their function and their potential applications in healthcare.

Keywords: Biopolymer; Drug delivery; Polymer gel.

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Chitosan/ graphene nanoplatelets based triboelectric nanogenerators for real-time sports applications

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Triboelectric nanogenerators (TENGs) based on natural polymers gained tremendous interest for their sustainability, eco-friendliness, and biocompatibility. Despite the potential advantages of natural polymer-based TENG sensors, there are still several issues pertaining to their low output efficiency and mediocre mechanical performance, restricting their application in biodegradable wearable devices. This study deals with the fabrication of a high-performance and eco-friendly chitosan-based TENG sensor via solvent casting method, using varied concentrations (1- 3 wt%) of graphene nanoplatelets (GNPs) as filler. Comprehensive investigations were conducted into the physicochemical, morphological, thermal, and electrical properties of the chitosan/ graphene nanoplatelets (CS/GNPs) composite films. Raman analysis revealed the presence of GNPs in the CS matrix, showing enhanced I_D/I_G values for all the composites compared to pristine GNPs. The XPS analysis showed the formation of CS/GNPs composites via amide linkages. Morphological analysis revealed that GNPs were embedded within the CS matrix, which tended to agglomerate at higher concentration of GNP (3 wt%). Furthermore, the triboelectric performance of the composite films showed an outstanding open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), and maximum power density of 166.25 V, 13.56 µA, and 44 mW/m^2 respectively, at 2 wt% GNPs concentration. The optimized CS/GNPs (2%) TENG sensor was successfully used to track real-time sports activities, distinguishing motions and basketball dribbling with different intensities and heights, respectively. Moreover, soil burial tests indicated promising biodegradation rates within six days, highlighting the potential of fabricated triboelectric layers in sustainable wearable technology and real-time activity monitoring.

Keywords: Chitosan, Graphene nanoplatelets, Triboelectric nanogenerator, Self-powered sensor · Sports activity monitoring

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Functional Porous Polymers *via* Macromolecular Engineering

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Over the last decade, the generation of organic porous (nano)materials with tunable pore sizes and desired functionalities has been the subject of increasing attention in materials science. Interest in such porous frameworks originates from the large variety of sustainable applications in which they are involved, *e.g.* monoliths for advanced chromatographic techniques, nanofiltration membranes, high specific area catalytic supports, as well as 3-D scaffolds for tissue engineering [1-5].

This lecture highlights the scope and limitations of three different approaches toward porous polymers with controlled morphology and functionality at different length scales. The first approach relies on the synthesis of diblock copolymers with functional groups at the junction between both blocks, followed by their macroscopic orientation, and the subsequent selective removal of the sacrificial minority block to afford ordered nanoporous materials with channels lined with chemically accessible functionalities (*e.g.*, COOH, SO_3H, SH, NH_2) [1,2]. The second strategy entails the preparation of functional doubly porous polymer networks through the use two distinct types of porogen templates, namely a macroporogen in combination with a nanoporogen. To generate the macroporosity, either NaCl particles or fused PMMA beads or Nylon® threads are used, while the lower porosity level is obtained by using a porogenic solvent [3,4]. Finally, 3-D macroporous scaffolds based on biodegradable polyesters have been engineered by electrospinning to generate nanofibrous biomaterials as tissue engineering scaffolds or wound dressings. The potentialities afforded by these approaches will be addressed, and some typical applications of the resulting porous materials will be illustrated [5].

Keywords: block copolymers, polymer networks, controlled degradability, tunable porosity, electrospinning.

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Reprocessable Polybenzoxazines and Polybenzoxazine Nanostructures for Energy Storage Application

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The molecular design flexibility of polybenzoxazine is currently being utilized by our research group to achieve a rational network that is suited for several intended applications. However, the permanent covalent crosslinks responsible for the interesting properties of thermosets hinder their reprocessability generating huge waste. Our research team is addressing this issue as well by incorporating dynamic covalent chemistry, such as imine, disulfide, etc. into the crosslinked network of polybenzoxazines, thereby producing a vitrimer for self-healing adhesives, coatings, and recyclable fibre reinforced composites. The modularity of various phenols and amines enables the design of functionalized monomer units with variable properties, including network flexibility, thermal and mechanical strength, optimal viscosity, dynamic linkages, and reprocessability. Carbonization is yet another feasible route for the reutilization of thermosets which has motivated us to validate the heteroatom-enriched network of polybenzoxazine as a viable candidate for deriving inherently doped carbon structures suitable for energy storage applications.

Keywords: Polymer Nanostructures; Supercapacitors; Hydrogen storage and release; Vitrimers, Composites.

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Innovative Polymers for High Performance Coating Application

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Safer, cleaner and sustainable coating is getting attention in recent times. At the same time consumer expectations are increasing day by day. This is leading to the need to develop high performance sustainable advanced materials. Polymeric binder being the heart of coating composition, research focus is more on development of new polymers for performance enhancement. Current research shows good amount of work being done on core-shell structure, cross linking technology, organic-inorganic hybrid materials, hyperbranched polymers along with biobased functional polymers for such applications. Development of suitable water-based paints to replace solvent based paints is also getting importance for safer environment. Some of our work in connection to these areas are summarized below.

New water based organic-inorganic nano hybrid resins were synthesised through sol-gel technique by using alkoxysilane modified acrylic resin, silane monomer and chitosan as functional components. The uniqueness of this process is the incorporation of chitosan and nano silica via in situ hydrolysis-condensation reaction. The coating based on such bio-based organic-inorganic nano hybrid polymer exhibited excellent antimicrobial activity, hydrophobicity and formaldehyde absorption ability which has potential for application in water based hygienic coating.

Similarly, nano MgO was incorporated into specially designed acrylic and hyperbranched alkyd through chemical modification. Such hybrid resin was neutralized with suitable base followed by dispersion in water. The coating based on such hybrid polymer exhibited long term antimicrobial efficacy due to the formation of stable polymer network through nano MgO and hybrid resin system.

Use of cross linkable monomers and core-shell structure with surface functionalisation resulted in development of high Tg and low MFFT binder, capable of delivering durable paints with low VOC. Nano silica was incorporated in acrylic moiety during emulsion polymerisation to balance hardness and flexibility of paint film. Such specially designed acrylic emulsions have unique particle size distribution for desired film formation along with dirt pick up resistance.

Synthesis of hydrophobic emulsion binder having desired film properties has been found suitable to develop water based anticorrosive primer to replace solvent based primers. Development of suitable water-based alkyd emulsion was used to make water-based paints having comparable performance to enamels. Getting the desired molecular weight and particle size distribution was critical in delivering such products.

The presentation will cover synthesis, characterization & application properties of such innovative polymers to deliver paint performance as well as environmental requirement.

Photoswitch tethered Peptide to Dictate the Fate of Supramolecular Polymerization

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Supramolecular polymerization enables the construction of functional architectures via reversible non-covalent interactions. The self-assembly process navigates complex energy landscapes, influenced by molecular symmetry, solvent composition, temperature, and external stimuli. Assembly follows mechanisms like isodesmic or cooperative pathways, with on- and off-pathways competing based on energy barriers. π-Conjugated systems (e.g., porphyrins, perylene bisimides) exhibit kinetic and thermodynamic states, modulated by light and chemical cues. Photoswitches like azobenzene enable precise control over material organization. In this regard, peptide amphiphiles (PAs) serve as versatile scaffolds for supramolecular assemblies, with π–π stacking and H-bonding interactions guiding variable nanostructure formation in response to variations in the local microenvironment. Additionally, anchoring stimuli-responsive moieties to peptide amphiphiles enable regulation of self-assembly pathway by various stimuli such as pH, temperature, light and many more.

Thus, we have designed a series of symmetric azobenzene-functionalized peptide amphiphiles, wherein the peptide sequence has been modified from amyloidogenic to non-amyloidogenic. This strategic point mutation was investigated for its influence on self-assembly dynamics and photoisomerization behavior. Kinetic analyses revealed that the amyloidogenic peptide fragment preferentially facilitated the formation of a kinetically trapped nanofibrous state. However, thermal perturbations induced transitions between distinct thermodynamic states, governed by the phenylalanine content and presence of co-solvent in the local microenvironment. A systematic evaluation of solvent composition, temperature was conducted to elucidate their roles in modulating self-assembly pathways and photoisomerization kinetics upon varying molecular structures from amyloidogenic to non-amyloidogenic peptide sequence.

Keywords: Azobenzene, Photoisomerization, isodesmic, cooperativity, peptide amphiphiles.

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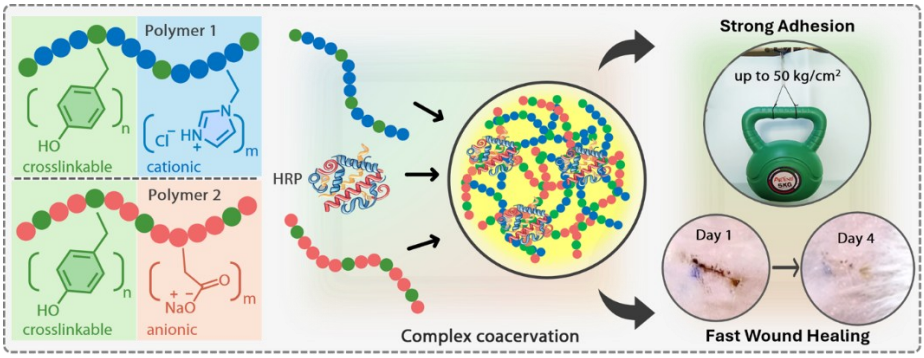
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Rapid Crosslinking of Polyamide Polymer Chains upon Exposure to Enzyme and Light to Produce Biocompatible Hydrogels and Tissue Adhesives

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Gelation can be induced by introducing either non-covalent, coordinate or covalent crosslinks in the polymer chains. In the recent times, attention has shifted towards employing benign crosslinking protocols to achieve crosslinks amongst polymers meant for biomedical applications. Towards this end, there's a strong interest in utilizing enzymatic or photochemical methods to induce hydrogelation. Our group had previously designed water soluble polyamide polyelectrolytes (PEs) based on poly(aspartic acid) framework that acted as effective underwater adhesives.[1] By tweaking the design, we created PEs that rapidly form hydrogels on exposure to either horseradish peroxidase (HRP) or to visible light in presence of riboflavin. When a mixture of counter PEs were employed, the resulting complexes emerged as effective adhesives that could strongly adhere diverse substrates such as wood, aluminum, leather etc. Very high adhesion strengths upto 10 MPa were achieved on wood substrates (Fig. 1).[2] When the PEC adhesive was tested on surface wounds of mice, the adhesives not only reduced blood loss but also allowed more effective wound healing with minimum scar formation, significantly outperforming the commercial cyanoacrylate-based tissue adhesives. These findings position the enzyme-cured PEC adhesives as promising contender in advanced wound care applications.



Figures 1. Enzymatic curing of polyelectrolyte complexes affords high-strength and reconstitutable biomedical adhesives.

Keywords: Polyelectrolytes, Hydrogels, Tissue adhesives, Enzymes, Hemostatic

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Porous Polymer Materials by Design: Versatile Fabrication Strategies for Sustainable Applications

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Porous polymers have emerged as a highly versatile class of advanced materials, offering lightweight architectures, tunable structures, and multifunctional properties.[1] Their unique combination of porosity, chemical diversity, and mechanical adaptability makes them key solutions to pressing global challenges, including the development of sustainable energy systems, advanced biomedical devices, and high-performance thermal insulation. Furthermore, polymer-based materials provide a powerful platform for designing and optimizing chemical synthesis processes, serving as catalysts supports, or reactive media to enable more efficient, selective, and environmentally friendly chemical transformations.

This contribution will present an overview of fabrication strategies for porous polymers developed within our research group, encompassing advanced approaches such as templating, phase separation and green chemistry-based synthesis. Special emphasis will be placed on systematically engineering processing–structure–property relationships to deliver application-driven functionalities, including tailored scaffolds for tissue engineering, efficient insulation materials with shape-memory and self-healing ability, and permeable supports for heterogeneous catalysis in flow chemistry. In addition, this contribution will highlight how controlled surface nanostructuring of porous polymers enables the design of multifunctional materials with enhanced performance.

By showcasing tailored porous polymer architectures in diverse formats – such as aerogels,[2] monoliths,[3] scaffolds,[4] and composites[5] – this contribution will highlight the fundamental design principles that bridge polymer materials science to transformative applications in health and sustainable technologies.

Keywords: biodegradable porous scaffolds, hierarchical porosity, macroporous monolith, nanostructured aerogel, sustainable materials.

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Green-light Wavelength-Selective Organic Solar Cells towards Agrivoltaics: From Lab to Fab

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The energy source of electricity in agriculture largely depends on fossil fuels, and solar cell technology has emerged as a promising alternative that could significantly reduce greenhouse gas emissions. Organic solar cells (OSCs) have attracted extensive attention due to advantages that include flexibility, light weight, and solution processability. Green-light wavelength-selective OSCs is a new type of technology in agrivoltaics, where the transmitted blue and red light can be effectively used to promote crop growth and green light is used for electricity production from solar light.1-3 For this purpose, we utilized a cost-effective and green-light wavelength-selective polymer, poly(3-hexylthiophene) (P3HT) as a donor and a fluorinated-naphthobisthiadiazole-based (FNTz-FA) nonfullerene acceptor (NFA), that was designed in our laboratory.4,5 This NFA possesses absorption bands in the green-light wavelength range of 500–600 nm, and thus the absorption of OSCs is complementary to the photosynthetic dyes of chlorophyll *a* and chlorophyll *b* (*Figure 1*). The FNTz-FA film shows an intense absorption with a good molar extinction coefficient in the green-light region, and it also possesses high chemical stability. As a result, the P3HT:FNTz-FA-based film showed an SG value of 0.59 and a PCE-GR of 11.7%. We optimized the device fabrication conditions, and 100 and 400 cm2- scale solar modules were successfully developed. The solar modules sustained efficiency after 180 days of storage under ambient conditions showing their potential to be employed in agricultural studies. We also investigated the influence that the P3HT:FNTz-FA films exert on the rate of photosynthesis and found that the green-light selective absorbance of the P3HT:FNTz-FA films showed non-obstructing characteristics for strawberry and tomato cultivation. Furthermore, preliminary investigations into the growth of tomatoes showed the potential of P3HT:FNTz-FA-based OSCs for agrivoltaics (*Figure 2*). These results demonstrate that green-light wavelength-selective OSCs are a promising candidate to realize novel agrivoltaics in greenhouses.

Keywords: Non-fullerene acceptors, Poly(3-hexylthiophene), Organic photovoltaics, Agrivoltaics.

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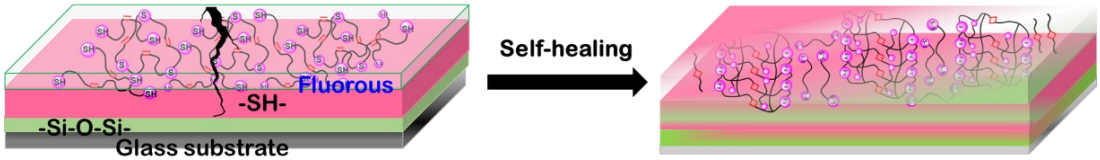
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Multiphase gradient self-stratified coating with self-healing ability

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Protective organic coatings are fundamentally polymeric composites with great complexity and variety in chemical compositions, macro-/microscale structures, and surface/interfacial characteristics. The components of a typical coating involve three layers, a binder, providing adherence to the metal substrate via chemical bonding and mechanical interlocking; a middle coat with various functionality, and a top coat to protect from weather and mechanical abrasion. However, multilayer coatings suffer from compatibility issues among different layers, cost, and other issues. While self-stratifying coatings capable of producing gradient multi-coat films by one-coat application offer outstanding performance by enhancing both the surface and the adhesion properties simultaneously at lower-cost, which are suitable for many special coatings and industrial applications.[1,2]



In this talk we shall discuss few well-defined multifunctional self-stratifying coatings developed from two distinct approaches;[3,4] 1) Blend of Fluorous/Thiol/Siloxane Copolymers: A blend of two incompatibility copolymers of fluorous/thiol/siloxane results in the spontaneous self-stratification into three layers, due to disliking interaction between fluorous with siloxane and a high tendency of fluorous layer migrate to the surface. 2) Universal Self-Stratifying Coating based on Siloxane-Tannic Acid-PVA: developed through the diffusion of self-assembled particles. The quality of these self-stratifying coatings is further increased by incorporating the self-healing abilities to enhance the safety index and extended lifecycle. Both of these polymer coatings show >80% healing efficiency. The gradient distribution in these layered systems was characterized by FESEM, EDS-dot mapping, WCA, and AFM. These multiphase gradient coating systems may be applied to various substrates like glass, metal surfaces, underwater windows, or cameras.

Keywords: self-stratified coating. Self-healing.

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Stimuli-responsive macromolecules and functional bio-based polymers for various applications

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Amphiphilic linear block copolymers,[1,2] dendronized polymers, linear-dendritic copolymers and denrimers[3] were synthesized using various controlled polymerization methods and azide-alkyne click reaction (CuAAC). Different stimuli-responsive groups such as pH-responsive acetal,[2] redox-responsive disulfide and UV-[2] and visible-light responsive[3] groups and temperature-responsive polymer chains[1] were installed in the polymers. Self-assembly of the synthesized polymers in aqueous solution showed micelles, vesicles and rod-like morphologies. Potential of these polymer assemblies for controlled drug release was explored by encapsulation and stimuli-responsive release of drugs in cellular uptake studies. Endocytic pathway of the drug-loaded micelles and apoptotic mechanism was investigated.

In the direction of sustainable polymer chemistry, squaraine dyes were shown to be efficient photoredox catalysts in photoinduced electron transfer-reversible addition fragmentation chain transfer (PET-RAFT) polymerization for synthesis of functional methacrylate polymers in aqueous medium and in continuous flow process.[4] Bio-based acrylates were also polymerized, modified using thiol-ene reaction and evaluated for adhesive properties. Further, novel bisphenol and biphenyl methyl ether monomers were synthesized from lignin-derived chemicals such as veratraldehyde, guaiacol and vanillin. Polycondensation method was used to synthesize (co)poly(ether sulfone)s containing pendant catechol moieties[5] and hyper-crosslinked polymer that were evaluated as redox active agent in zinc-ion batteries and as active coating layer on conventional polypropylene separator in lithium-sulfur batteries, respectively.

Keywords: Block copolymers, Controlled radical polymerization, Polycondensation, Drug delivery, Batteries

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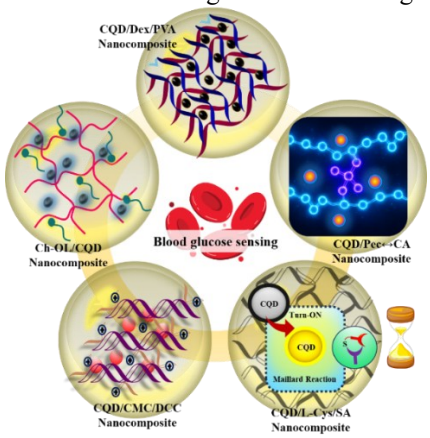
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Mechanistic Insights into Carbon Quantum Dots Imprinted Polysaccharides for Glucose Sensing

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This work explores the design of a fluorescence-based glucose sensing platform utilizing carbon quantum dots (CQDs) as versatile fluorescent probes. Owing to their low toxicity, excellent optical performance, chemical robustness, ease of synthesis, and environmental friendliness, CQDs represent a promising class of nanomaterials for biosensing applications. In this study, CQDs are derived from the leaves of medicinal plants including Aloe vera, betel (*Piper betle*), arrowhead (*Syngonium podophyllum*), spider plant (*Chlorophytum comosum*), and purple orchid (*Bauhinia purpurea*) harnessing their natural abundance and inherent bioactive components. These plant-derived CQDs are embedded in polysaccharide-based nanocomposites for non-enzymatic glucose sensing via fluorescence modulation. Five distinct systems are designed: (i) Dextran/PVA-CQDs (Aloe vera) showing a hydrogen-bond driven *"switch-OFF"* response (LOD 61.1 µM), (ii) chitosan-CQDs functionalized with oleic acid enabling a *"Turn ON-OFF"* mechanism (LOD 1.51 µM), (iii) carboxymethyl cellulose-CQDs utilizing DCC-assisted esterification with an ultra-low LOD of 7 nM and dual linear ranges, (iv) alginate-CQDs activated by L-cysteine exhibiting a thiol-mediated *"Turn OFF-ON"* mechanism (LODs 1.3 µM and 104.66 µM), and (v) pectin-citric acid-CQDs operating via competitive esterification with dual ranges (LODs 2.97 µM and 252.92 µM). All platforms showed excellent stability under varying ionic and pH conditions, high selectivity against interfering biomolecules, and reliable performance in human serum samples consistent with glucometer readings. These findings highlight the promise of cost-effective, enzyme-free, and biocompatible CQD-polysaccharide nanocomposites as next-generation fluorescence-based sensors for clinical glucose monitoring and diabetes management.



Keywords: Carbon quantum dots; Polysaccharide; Glucose sensing; Fluorescence technique; Human blood serum.

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Rethinking Tire Wear Particle Collection:

Why Simplified Laboratory Studies Are Essential for Emission Reduction

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Reducing emissions from tire and road wear particles (TRWPs) is a growing priority in the context of environmental protection and sustainable mobility. A major challenge lies in the collection and analysis of these particles, particularly those generated in real-world driving conditions directly behind the tire. While promising concepts for on-road particle capture exist, practical implementation remains technically demanding and scientifically uncertain due to factors such as turbulent airflow, surface adhesion, and rapid particle dispersion.

In this study, we explore an alternative strategy focused on simplified laboratory based investigations. Rather than attempting to replicate real-world tire abrasion, we use the DIN abrasion test (ISO 4649) as a baseline method. Its role is not to simulate actual tire road interaction, but to offer a widely accessible and standardized means of generating and analyzing wear particles under controlled conditions. This approach enables consistent evaluation of how different material parameters and mechanical responses influence wear particle formation and recovery rates.

Preliminary observations indicate that even under ideal lab conditions, full recovery of rubber abrasion particles (rAPs) remains difficult, due to factors such as particle adhesion, secondary dispersion, and handling losses. If complete particle capture cannot be assured in such a controlled setting, this raises questions about the feasibility of achieving reliable real-time collection behind a moving wheel under far more complex, dynamic conditions.

We argue that laboratory studies, even those based on simplified test methods, are indispensable for understanding the fundamental mechanisms that lead to particle formation. This understanding is a prerequisite for designing tire materials and structures that minimize emissions at the source.

Ultimately, progress in reducing TRWP emissions depends not only on engineering better collection methods, but on rethinking abrasion as a material driven process that must first be understood in detail before it can be managed in practice.

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Shifting the paradigm in reinforcement of polymers

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Carbon dots (CDs) belong to a newly discovered quasi-spherical carbon nanomaterial, having size lower than 10 nm (Figure 1 (a)) and typically composed of carbon [1]. The most important hallmark of CDs is bright fluorescence (Figure 1(b)), tunable across the visible range, which has revolutionized the traditional paradigm of carbon as a black material unable to emit light [1]. The synthesis of CDs can be achieved via two approaches: (i) top-down methods and (ii) bottom-up methods (Figure 1(c)) [1]. The synthesis of CDs is generally regarded as more cost-effective and experimentally accessible than fabrication of graphene and nanotubes. Additionally, the substantive number of oxygenic moieties integrated on the surface of CDs makes it feasible for functionalization with other compounds and endows them with splendid dispersibility in both polar and non-polar liquids. In literature, there are a few reports that discuss the effect of CDs in a polymer matrix for different applications such as optical sensing, biomedical imaging, thermal stability, optical devices and solar devices. However, till date, only a limited number of studies have investigated the reinforcing ability of CDs in various polymers. It is well known that enabling covalent bonding between the fillers and the polymer chains is one of the prime factors for significantly enhancing the properties of the polymer composites. We are among the earlier researchers who have systematically exploited the ability to functionalize CDs with various functional groups, which in turn enable them to form strong covalent interaction with various polar and non-polar polymers such as natural rubber (NR) latex, carboxylated acrylonitrile butadiene rubber (XNBR) latex [1-3], carboxylated styrene butadiene rubber (XSBR) latex [4], thermoplastic polyurethane (TPU) and epoxy resin. We have shown that covalently attaching a small concentration (<2 phr) of functionalized CDs into NR latex, XNBR latex, XSBR latex, TPU and epoxy resin leads to a significant improvement in the physico-mechanical properties of the polymer nanocomposites. Based on our detailed investigation, we hypothesize that CDs can be projected as a potential alternative nanofiller for other environmentally unfriendly and/or high-priced fillers/nanofillers such as carbon black, silica, nanotubes and graphene. Owing to the severe environmental concerns and commercial factors associated with other nanofillers, CDs has an excellent potential to be used in various end-use applications from an eco-friendly, low cost and sustainability perspective.

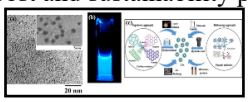


Figure 1 (a) HRTEM micrograph of CDs, (b) Blue fluorescence of CDs under UV irradiation and (c) Pictorial representation of various synthesis methods to prepare CDs

Keywords: Carbon dots, Filler, Polymer, Rubber, Reinforcement

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Reinforcing and Hydrophobic Polymer Coating on Kraft Paper for Agricultural and Packaging Application

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The development of sustainable and high-performance coatings is essential for expanding the utility of kraft paper in packaging and mulching applications. Despite its wide use, kraft paper suffers from poor strength, water repellence and durability. To address these challenges, we investigated coating strategies aimed at enhancing functionality while maintaining environmental sustainability. In one approach, cellulose nanofiber-reinforced colloidal polymer nanocomposite of poly(styrene-*co*-2-ethyl hexyl acrylate) copolymer was synthesized by mini-emulsion polymerization. The nanocomposite films showed enhanced tensile strength (up to 7.8 MPa) and elongation (up to 1096%). When coated on kraft paper, the tensile index increased from 20.3 to 31.0–45.1 Nm/g, with water contact angles (WCA) of ~120°, demonstrating strong reinforcement and water repellence. In another approach, a renewable bio-based coating was developed using crosslinked alkyl chitosan (Ch-ODA). Chitosan was crosslinked with pentaerythritol triacrylate and grafted with octadecyl amine, confirmed by FT-IR and solid-state ^{13}C-NMR. Dip-coated papers with Ch-ODA, showed improved tensile index (from 17.1 to 32.8 Nm/g), higher WCA (from 81.5° to 119.8°), and excellent durability under abrasion and peeling tests. The coatings reduced porosity, were compostable in soil, and demonstrated practical use as a sustainable alternative to plastic mulches in agriculture. These strategies highlight pathways to multifunctional, environmentally friendly coated paper materials for agricultural and packaging applications.



Figure. a) WCA of the uncoated and coated kraft papers, b) coated kraft paper prevented the wetting of the surface by juice, milk and water c) coated kraft paper in mulching for Melon cultivation at the outskirts of Hyderabad.

Keywords: Paper coating, Kraft paper, Water resistance, Compostable, Paper mulch.

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N-isopropylacrylamide based monomers having 'Y' type pendant groups with varying alkyl side-chain length: synthesis, polymerization, characterization, physical properties and application studies of their polymers

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N-isopropylacrylamide based *N*-alkyl-*N*-(3-(isopropylamino)-3-oxopropyl)acrylamide] (Mn) monomers having 'Y' type pendant group with varying alkyl chain lengths (n = 1–17) have successfully been synthesized and polymerized *via* reversible addition–fragmentation chain transfer (RAFT) polymerization. Some copolymers with different comonomers have also been synthesized. These polymers are well-characterized by ^{1}H NMR, Fourier transform infra-red (FTIR) spectroscopy, gel permeation chromatography (GPC), differential scanning calorimetry (DSC), powder X-ray diffraction (PXRD), small angle X-ray scattering (SAXS), atomic force microscopy (AFM), transmission electron microscopy (TEM), rheometer, dynamic light scattering techniques. Our understanding about the effect of the use of varying RAFT agent, polymerization solvent, alkyl chain-length, monomer concentration, type and composition of co-monomers, bulk and thin film nature, annealing conditions etc. on the thermal, solution (solubility, thermo-responsiveness, rheological) properties and morphology of the formed polymers will be presented here. Moreover, the application of these polymers for different applications like drug delivery, nanoparticle synthesis etc. will also be presented here.

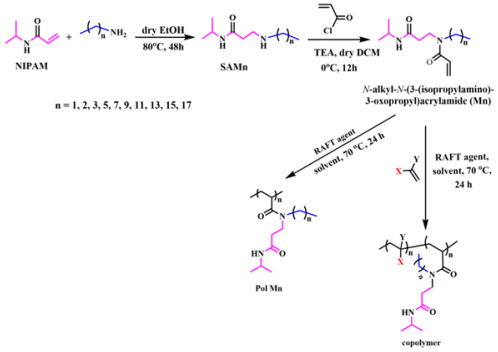


Figure 1 – Synthesis of polyMn.

Keywords: RAFT polymerization, amphiphilic properties, thermoresponsive properties, thermal properties, morphology study.

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2D Nanomaterials Incorporated Poly (vinylidene fluoride) Nanocomposites Toward Piezoelectric Energy Harvesting and Piezocatalytic Dedradation

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In recent times, 2D nanomaterials-based poly(vinylidene fluoride) (PVDF) nanocomposites have shown extraordinary performance in energy harvesting and piezocatalytic degradation of various dyes in water remediation. In this context, PVDF/graphene oxide (GO) nanocomposite has shown as efficient energy harvester in solution-casted nanocomposite film as compared to compression-moulded counterpart [1]. This was due to the higher polar phase formation in solution-casted nanocomposite film. Further, interfacial interactions between -COOH functionality of GO and PVDF led to polar phase conformations during PVDF crystallization. We have also explored the role of molybdenum sulphide (MoS_2) in promoting higher polar phase formation in solution-casted PVDF/MoS_2 nanocomposite [2]. Moreover, the influence of β-cyclodextrin (β-CD) and mono-lithium adipate (Li-AA) in exfoliating MoS_2 to few-layered MoS_2 nanosheets was also explored, wherein β-CD exfoliated MoS_2 and Li-AA exfoliated MoS_2 showed significantly higher polar phase formation as compared to pristine MoS_2 [3,4]. This has led to higher piezoelectric coefficient (d_{33} value) and a significantly higher output voltage and short-circuit current of the nanogenerators fabricated from these nanocomposites. A structure-property relationship study was attempted to highlight the piezoelectric performance and piezocatalytic degradation of various dyes in water remediation.

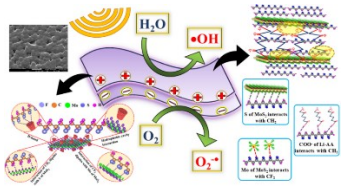


Figure 1 Schematic presentation showing the interactions between MoS_2, β-CD, Li-AA and PVDF chains and the mechanism of piezocatalytic degradation of the PVDF based nanocomposite.

Keywords: PVDF, MoS_2, Piezoelectricity, Piezocatalysis, Dye degradation.

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Organic Nanoporous Materials for Energy and Environmental Sustainability

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Interfacial polymerization developing processable nanoporous organic thin films of crystalline covalent organic frameworks (COFs) could be promising for applications from molecular separation to energy storage.1,2 In this context, we achieved a room-temperature transformation of an organic imine cage to a free-standing COF film at the aqueous-organic interface using an amine linker exchange strategy, producing highly porous and crystalline COF films in 24 h.3 The COF film showed high permeance and excellent molecular sieving performance. Additionally, a 2D electrochromic COF (EC-COF) film having tunable redox functionalities was developed at the solid-liquid interface with broad absorption across the UV-to-NIR range, showing three-state anodic electrochromism, high color contrast (~ 60 % in the NIR), and fast switching.4 A prototype device using the EC-COF film as a safety indicator for electronic circuits has been developed.4 We further expand the scope of redox-active amorphous porous organic polymers in sodium-ion battery electrodes.2 The key aspects of some of these findings will be presented.

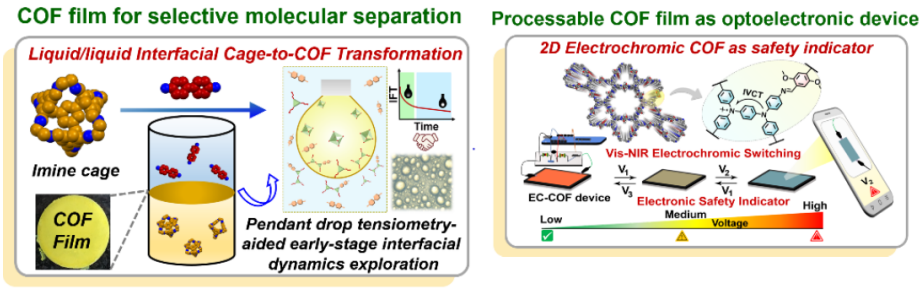


Figure1: The pictorial depiction illustrating the multi-faceted role of organic nanoporous materials as processable crystalline films at liquid-liquid interface and electrode-electrolyte interface demonstrating promising potential in molecular separation and optoelectronic devices.

Keywords: Porous organic polymers, Covalent organic frameworks, Interfacial polymerization, Electrochromic device.

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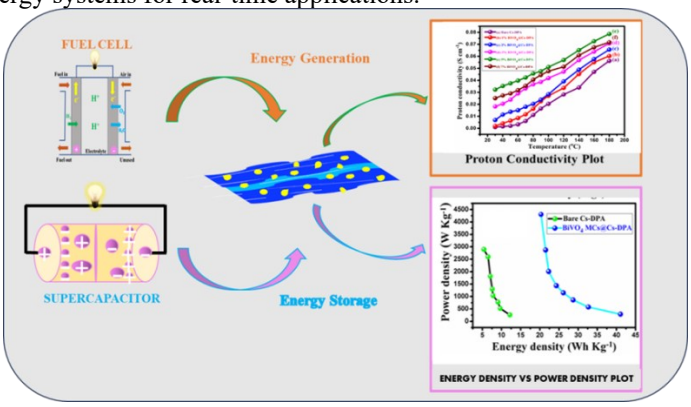
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Polymer electrolyte membrane-based sustainable nanomaterials for energy generation and energy storage applications.

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The growing depletion of fossil fuels and their adverse environmental impact have intensified the search for sustainable source of energy alternatives. In this context, the development of advanced materials for the fabrication of efficient fuel cells and supercapacitors has gained significant attention, since these devices enable the generation of clean energy and efficient energy storage. Current research efforts focus on designing of high-performance, durable, and cost-effective materials that can enhance the electrochemical efficiency and meet the increasing global energy demands**.**The growing demand for sustainable and efficient power conversion systems, such as fuel cells (FC) and energy storage system namely Supecapacitor as foisted to synthesize, advanced membrane materials that provide high ionic conductivity, mechanical robustness, chemical stability, and cost-effectiveness in both systems. Keeping this in mind, my research has significantly contributed to improve the design and production of high-performance polymer electrolyte systems.This lecture focuses on fabrication of a membrane electrode assemblyusing the solvent-casting method, by incorporating 1–7 wt% $BiVO_4$ microcubes (MCs) into a chitosan–dendritic polyamidoamine (Cs–DPA) matrix. Among the resulting polymer membranes derived from compositions, the membrane with 5 wt% $BiVO_4$ MCs-dispersed Cs–DPA membrane showed the most promising performance, achieving a proton conductivity of 7.86×10^{-2} S cm^{-1} and a specific capacitance of 895.65 F g^{-1} at 1 A g^{-1}, both significantly higher than the pristine Cs–DPA membrane. These findings highlight the synergistic role of $BiVO_4$ MCs and DPA in enhancing ion transport and charge storage, establishing the material as a versatile candidate for integrated fuel cell and supercapacitor technologies. Additionally, we have also synthesised acid-doped nanoparticle-reinforced polymer membranes, like phosphoric acid-doped poly(ethylene imine)/poly(vinyl alcohol) composites integrated with ZrO_2 nanoparticles, and demonstrated the same as an efficient polymer electrolyte membrane operated at medium-temperature fuel cell applications.Therefore, my lecture will focus on valuable insights into the structure-property-performance relationships of composites of membranes, and their contributions onto the development of next-generation, high-efficiency electrochemical energy systems for real-time applications.



Keywords: Fuel cell, supercapacitor, energy density, power density, open circuit voltage.

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Engineering Bioactive Composite Feedstock with Shape Memory Behaviour for Additive Manufacturing of Bone Substitutes

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The limited availability of suitable feedstock materials for 3D printing has significantly hindered progress in artificial bone graft research. This study aims to advance bone tissue engineering by developing a commercially viable, bioactive composite feedstock with shape memory properties capable of fabricating bone structures that accurately replicate the intricate mechanical, biological, and chemical functions of native human bone. In this work, we developed wollastonite reinforced triphasic composite tissue scaffolds that hold significant promise for substituting bone graft in Orthopedic applications. To substantially enhance the toughness of PLA with minimum reduction in stiffness, PLA/PCL blends were prepared where PLA is a major component, PCL is a minor component, and wollastonite microparticles could act as an osteoconductive ceramic phase to harness the Osteogenic properties from the porous scaffolds. It is worth noting that the soft phase PCL in the triphasic scaffold could act as switching agent to induce the shape memory behaviour of triphasic scaffolds. This work could spark new ideas of advanced functional biomaterials and biomanufacturing and approaches for more efficiently boosting new vascularized bone formation for regenerative engineering.

Keywords: Composite 3D filaments; Fused Filament Fabrication; Bioactive scaffolds; functionalized nanomaterials; Tissue engineering and regenerative medicine.

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All-dry synthesis of polymer coatings for sustainable, biomedical and energy applications

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Chemical vapor deposition (CVD) is a well-known technique for the synthesis of inorganic coatings and thin films. Milder variants, such as initiated CVD (iCVD) and oxidative CVD (oCVD), enable the synthesis of organic polymers. In these processes, a monomer and an initiator or oxidant are introduced into a vacuum reactor in the vapor phase, leading to one-step surface polymerization. These techniques deposit polymer films on delicate or porous substrates, ensuring high coating conformality.

We have used iCVD to develop materials with tunable and gradient mechanical stiffness. Bifunctional monomers like allyl methacrylate enable thermal radical initiation while preserving one functionality for UV crosslinking, creating stiffness gradients. This makes the materials suitable for implantable scaffolds requiring tunable mechanical properties. We also create sustainable adhesives which are thermoreversibly debonded in a residue-free manner.

Additionally, we synthesized polypyrrole using oCVD, integrating polymer synthesis, doping, and film formation in a single step. By optimizing deposition temperature, reactor pressure, and oxidant-to-monomer ratio, we achieved homogeneous polypyrrole films with record conductivity of 180 S cm^{-1} for a solvent-free method. These polymers were applied to sensors and energy storage. For piezoresistive strain sensors, polypyrrole was coated onto flexible, porous substrates like electrospun fiber mats, phase-separated hydrogel membranes, and 3D-printed lattices, allowing tunable mechanical and electrical properties. Results on strain sensing behavior, gauge factors, and cyclic stability will be presented. For electrochemical energy storage, polypyrrole was coated on a carbon fiber mat and characterized via cyclic voltammetry, galvanostatic charge-discharge, and thermal stability tests. This presentation will highlight recently developed polymers for sustainable, biomedical, and energy applications.

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Functional Biopolymer Nanocomposite Materials for Food Packaging Applications

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The development of bio-polymeric materials is exceedingly gaining importance as a potential material for the replacement of petroleum-based material. Polysaccharide based biopolymers are the emerging material to replace petroleum-based material. They have an excellent film-forming property and are extensively used for the formation of polymeric films. However, biopolymers are highly sensitive to moisture, restricting their industrial application. Various strategies such as composite formation, blending, cross-linking, hydrogel formation etc., have been employed to overcome such drawbacks. Packaging is necessary for conserving and protecting food from deteriorating agents such as physical, chemical, microbiological, or other risks that could compromise its quality or safety. Biopolymer are potential material that are non-toxic, biodegradable, low-cost, and environmentally friendly material for use as packaging material. Therefore, with the rapid advancement and development of technology, the focus has shifted towards the fabrication of smart and active packaging materials to detect and report food quality in a real-time fashion. Such smart and active packaging systems respond to signals while interacting with the food-packaging environment. So, in this talk I discuss our work on fabrication of crosslinked guar gum-chitosan composite film without using any plasticizer fabricated via the solution casting method. The fabricated biopolymer composite film demonstrated superior properties like high stability in water, good mechanical properties etc. The crosslinked guar gum-chitosan composite film also shows a high contact angle and low water vapour permeability when compared with the film of chitosan. We introduced functionality in the bio-polymeric material to make it into a smart material like making it as a sensor or introduce antimicrobial property. In this regard, we fabricated guar gum- sodium alginate blending with glucose-glycerol carbon dots nanocomposite film can be used to detect relative humidity. The fabricated nanocomposite film was an excellent smart sensor based on the fluorescence 'on-off' mechanisms against humidity. We also developed biopolymer-mushroom nanofiber composite xerogel film which is fabricated by green process, chemically resistant, edible, and printable. In addition, sodium alginate-nanocellulose-based active composite film for edible oils packaging applications was also developed. Finally, biopolymers are potential materials that will eventually replace petroleum-based polymers in various applications, including packaging applications. One of the systems that will be pre-requisitely required is the sealing of biopolymer. Conventional sealing techniques are not suitable for sealing biopolymers. we developed a glue formulation that is found to be effective in joining two biopolymeric surfaces. Hence, all such biopolymer films discussed in the talk are potential materials as smart packaging material.

Keywords: Biopolymer; Nanocomposite; food packaging; chitosan; guar gum

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Our Latest Polymer Technologies For Combating Climate Change

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Plastic pollution created by polymeric materials from petrochemical feed and climate change have a deep interconnection. The plastic characteristics are deeply altered because of rising temperatures and moisture due to climate change, resulting in the contribution of waste, generation of microplastics and release of hazardous substances into the atmosphere. It is of global importance to understand these climate driven effects and offer appropriate solutions [1]. It is completely understood that there exists a self-reinforcing cycle between climate change and pollution from plastics synthesized from monomers derived from the petrochemical feed (Figure. 1). Synthetic biodegradable polymers are the new generation of macromolecules that can mitigate the effects discussed and many of them obey the principles of "circular economy" [2].

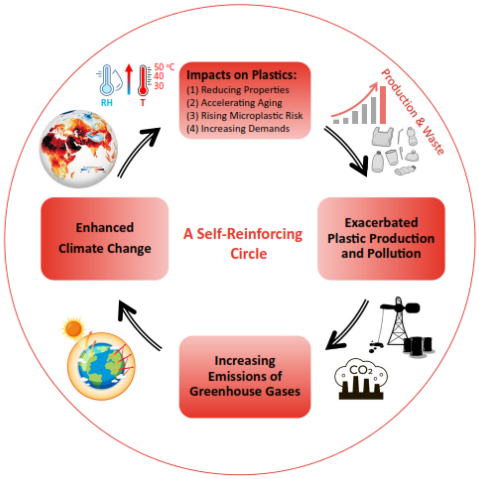


Figure. 1: Self-reinforcing cycle between climate change and pollution from conventional plastics

Since last few years, our laboratory has conceived modern technologies (TRL-4) towards the synthesis of polylactic acid (PLA), poly(cyclohexene carbonate) (PCHC) and polybutylene adipate terephthalate (PBAT). These synthetic biodegradable polymers are in huge demand in the global market today [3].

Keywords: Climate change, PLA, PCHC, PBAT

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Sustainable Curing and Bio-Based Reinforcement Strategies for Elastomers

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The rubber industry is at a critical juncture where environmental and regulatory pressures demand a transition from traditional, toxic vulcanization and compounding systems toward greener alternatives. This lecture presents two innovative approaches designed to meet these challenges in epoxidized natural rubber (ENR) systems. The first part focuses on replacing classical sulfur vulcanization particularly the use of toxic sulfur-organic accelerators with a diacid-based curing system. This non-toxic, metal-free approach enables efficient crosslinking through carboxylic acid-epoxide reactions, offering improved thermal and oxidative stability while mitigating environmental and health concerns. This strategy paves the way for cleaner rubber formulations aligned with REACH and other emerging global regulatory frameworks.

In the second part, we shift attention to lignin, a bio-based and widely available byproduct of the paper and biofuel industries. Through high-temperature reactive mixing, lignin undergoes in-situ chemical transformation into an active reinforcing phase within the rubber matrix. This process enhances interfacial interaction and dispersion, leading to significant improvements in mechanical properties, thermal resistance, and overall composite performance. Together, these two innovations represent a forward-looking vision for sustainable elastomer technology eliminating hazardous additives while utilization of renewable resources to create high-performance, environmentally responsible rubber materials.

Keywords: Epoxidized Natural Rubber, Di-acid network, Lignin, Reactive mixing, Reinforcement

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Advantages of E-beam cross-linking for manufacturing special cables

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APAR Industries limited is multiproduct manufacturing organization. APAR manufactured three products namely speciality oil, overhead conductors & speciality cables, APAR exports these three products around 140 countries. APAR products cater industries mainly railway, renewable energy, mining, transformer, industrial, nuclear, atomic, motor & generators, telecommunication, power transmission & distribution, shipping including wires & cables. APAR manufacturing facility spread over throw-out country with one facility outside country. APAR has five E-beam accelerator for cross-linking cables including other application. APAR manufactures speciality cables both by chemical and E-beam curing. E-beam curing cables having thin wall insulation and sheath w.r.t. chemical cured cable. Due to low thickness & E-beam curing these cables are suitable for Railway, Shipping, Submarine and other critical application. APAR developed E-beam cross-linked Halogen free fire protekt cable for house wiring application.

Harnessing Click Inspired Chemistry for Tailored Macromolecular Architectures: From Smart Functionalization to Porous Polymer Networks

Subrata Chattopadhyay*

Click inspired chemistry has become a cornerstone of modern macromolecular design, combining synthetic efficiency with structural precision with unmatched reliability, and modularity[1,2]. In this regard our work is focused on creating functional macromolecules whose topology and functionality are precisely controlled using efficient and click reactions. These molecular design elements—often overlooked—are in fact the "architectural codes" that dictate how polymers self-assemble, how they phase-separate in colloidal systems, and how the resulting bulk materials express their unique morphologies and properties. By decoding these relationships, we turn molecular blueprints into purposeful materials.

This talk will particularly explore how click-inspired reactions (particularly aza-Michael and triazolinedione-based reactions) can be strategically applied to construct well-defined polymers, nanomaterials and extend their utility into porous polymer networks. Few selective examples from our recent works will be discussed to showcase their application to selectively functionalize PEGs with precise topology and functionality to establish them as excellent class of selective and nontoxic antimicrobials[3,4]. The focus will then shift to porous organic polymers, where click chemistry provides a versatile route to develop frameworks with tunable structures and chemical environments. This helps us to establish some of the flagship materials in their relevant application field[5]. Finally, a brief overview will be given to showcase how such reaction platforms can be used as a surface engineering toolbox to develop a series of fluorescent nanomaterials for selective sensing applications[6,7]. Overall, these advances illustrate how simple sustainable synthetic philosophy can unify diverse material classes, bridging molecular precision with macroscopic functionality. By highlighting both conceptual strategies and material outcomes, this presentation emphasizes the central role of click chemistry in advancing next-generation polymeric and porous materials for a wide spectrum of scientific and technological frontiers.

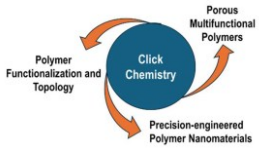


Figure 1: Harnessing Click reactions for next generation polymers and materials

Keywords: porous polymer, functional poly(ethyleneglycol)s, fluorescent nanomaterial, smart polymers.

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Sustainable Bio-based Additive for Next-Gen Rubber Compounding

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The development of sustainable alternatives to non-renewable industrial chemicals is gaining momentum, with coconut shells emerging as a valuable biomass source. Pyrolysis of coconut shells yields a phenol-rich liquid extract—Coconut Shell Oil (CSO)—capable of replacing multiple rubber-compounding ingredients. This study evaluates CSO as a multifunctional additive in styrene–butadiene rubber (SBR) systems. CSO demonstrated effective plasticization with low harmful chemical content and exhibited co-vulcanization behavior. Its reaction with sulfur forms resinous structures that enhance mechanical strength, flexibility, and thermal stability. CSO-filled vulcanizates (300 KCS) showed a six-fold improvement in De Mattia flexing resistance over antioxidant-filled compounds (50 KCS). Thermogravimetric analysis revealed a significant increase in the onset of volatilization temperature, from 250°C to 377°C. In silica-filled SBR, CSO replaced up to 50% of conventional silane coupling agents while promoting the silanization reaction. This led to improved reinforcement, better dynamic mechanical properties, reduced Payne effect, and enhanced scorch safety. CSO also served as an alternative to amine-based antioxidants due to its phenolic components, offering higher initial mechanical properties, though slightly lower retention after ageing.

Overall, coconut shell–derived materials offer a promising pathway toward sustainable, bio-based rubber compounding.e format, including tables, figures and references.

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Sustainable thermosets: From concept to impact

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The escalating depletion of fossil fuel reserves, coupled with the growing burden of waste accumulation, underscores the urgent need for sustainable polymeric materials. Polybenzoxazines, a class of thermally curable thermosetting resins, exhibit superior thermal, mechanical, and chemical properties compared to conventional phenolic resins. Importantly, their synthesis aligns with green chemistry principles—utilizing bio-renewable feedstocks, operating under solvent-free conditions, and generating minimal toxic byproducts. Our research group leverages the molecular design versatility of polybenzoxazines to enable copolymerization with diverse comonomers, including elemental sulfur[1–5]. This structural adaptability also facilitates stimulus-responsive depolymerization, paving the way for closed-loop recycling strategies. These attributes render polybenzoxazines highly suitable for advanced applications such as re/debondable adhesives, antibacterial coatings, water purification membranes, battery cathodes, and self-healing materials.

Keywords: Upcycling, Reprocessability, Closed-loop, Circularity, Sustainability, Polybenzoxazine.

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Sustainable Upcycling of Polyethylene terephthalate (PET) Waste for Energy Storage Application

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Universal solid waste management and its hazardous effects on the ecology, ecosystem, and the global human health index are some of the major issues that are currently threatening our future. Due to the rapid growth in global population and the related demands, the production of polymer waste materials is increasing day by day. In order to have a better solution to polymer waste management, the best ethical way is to convert polymer waste materials into valuable carbon-based nanomaterials (CNMs) such as CNT, graphene, and carbon quantum dots (CQDs), carbon nano fibers(CNFs) etc which can further work as precursors in energy storage devices. One-dimensional nanostructured Carbon nanofibers (CNFs) and their network CNFN retain a similar special properties and similar multi-functionality to carbon nanotubes, but they exhibit a few advantages, like easier production, lower cost, lower crystallinity, and more defects. Therefore, CNF-based nanomaterials have been widely used for applications relating to energy conversion/storage, catalysis, sensors, adsorption/separation, and biomedical engineering. Due to their high specific surface area, interconnected porous structure, light weight, and high mechanical strength, CNF-based three-dimensional (3D) nanomaterials have attracted more and more attention in many fields, especially in energy production/storage and environmental science. In this work, we will demonstrate the development of CNFN based nanocomposites for energy storage applications. To achieve this aim, typical design strategies for the production of CNFN-based 3D nanomaterials will be done by electrospun production of polymer nanofiber network (PNFN) and further carbonization at high temperature. These CNFNs will be utilized for fabrication of flexible electrodes for supercapacitor application for portable and wearable devices. Combining electrospinning and carbonization process, polymer waste electrospun membrane can be converted to carbon nanofiber networks (CNFN) with very large surface area that endows their great potential to be used in energy storage applications. By a simple optimization of carbonization, the carbon nanofiber networks can reach a large surface area and excellent specific gravimetric capacitance.
We are proposing a facile and scalable method for synthesizing high-performance CNFN electrode materials for supercapacitors with specific gravimetric capacitance of more than 300 F g-1after 10000 cycles, with a capacity retention of more than 90%.

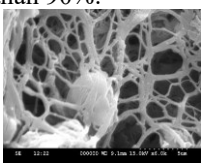


Figure: Carbonized Electrospun PET Chitosan Membrane.

Keywords: Polymer nano fiber (PNF), Carbon Nano Fiber (CNF), Electrospinning, Polyethylene terephthalate (PET)

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Twin-Screw Compounding for 3D Filament Production

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3D printing has emerged as an invaluable tool for creating three-dimensional objects by extruding molten plastic through a small nozzle. Although a variety of materials can be used in the 3D printing process, including concrete, human cells, and metal, polymers are still the most common. The "ink" for these fused deposition 3D printers is polymer filaments with a defined and very constant diameter. To make these filaments from a basic polymer, simple single-screw extruders are used. Single-screw extruders have high pressure build-up and constant output, which ensures a constant filament diameter. However, on the downside, single screw extruders are very inefficient mixers, which limits their usage for filament production to readily available polymers or a multiple-step process.

For advanced polymer compounds or customized product formulations, twin-screw extruders, owing to their high mixing capacity, have to be used. Such twin-screw extruders allow for the compounding of multiple ingredients into a homogeneous blend during the extrusion process. The twin-screw extrusion process results in a slightly pulsating flow output, which makes it difficult to maintain a constant filament diameter. The solution to this challenge is the use of a melt pump located between the end of the extruder and the strand-forming nozzle. The regulated flow of material ensures that the filament is constant in diameter. Using a twin-screw extruder not only ensures the high homogeneity of the material but also ensures a constant diameter of filament.

Metal-linked Polymers as Functional Materials

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Though metallopolymers/metal-linked polymers have been studied quite well in the literature, however, the synthetic strategy and structure-property analysis are limited to only few variants and hence the use of this class of polymers in developing functional materials did not progress well. In recent years, we have focused our attention in developing functional materials such as redox active polymers, catalytic polymers, and anti-cancer nano-surface, fluorescent active polymers etc. from metal-linked polymers. In all our study we used ferrocene and its derivatives as metal source; however similar strategies can be used from other metal sources. In a series of articles published by us, we demonstrated that ferrocene or ferrocene linked polymers can be attached/grafted/copolymerized with hydroxy terminated polybutadiene, a well know polymeric binder for composite propellant (CP) formulation, to develop burn rate modifier-cum-binder for the use in CP formulation which has significant demand in aerospace and defense applications. Similarly, we also shown that poly(ferrocenyl)-grafted-silica nanoparticle (SiNP) template can be utilized to develop bimetallic core-shell nanostructures consisting Fe as shell and Al as core for the use as fuel-cum-burn-rate catalyst. In another set of works, we developed anti-cancer nano-surface by strategically grafting appropriate poly(ferrocenyl) structure on the solid nano-surface. Further, we have developed a series of block-copolymers consisting hydrophobic and hydrophilic chains and one poly(ferrocenyl) block, and these blocky structures displayed crystallization driven self-assembly resulting redox-active structural modulation. Overall, I will touch-upon our results on the development of metal-linked polymers as advanced functional materials.

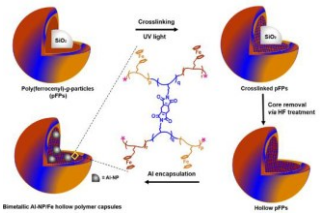


Figure: Scheme for the development of bi-metallic core-shell nanostructure using poly(ferrocenyl) templating.

Keywords: RAFT polymerization, Nanostructured Polymers, Ferrocenyl Polymers, Burn Rate Catalyst, Anti-Cancer Surface

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Cellulose-Hybrid Fillers for Green Composites

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Plastics are seen as both a burden and a blessing for modern society. The development of new materials must be based on renewable raw materials and also be eco-friendly at the end of their life cycle, which is therefore a top priority. We demonstrate therefore the development of a hybrid filler system consisting of cellulose fibers with minerals attached to the surface. These kind of fillers had been used in thermoplastics including biobased PLA. Such kind of ternary bio-composites showed superior modulus while comparable impact properties were achieved. After successful transfer to pilot-plant scale the composites were additionally tested for its burning properties with slightly reduced LOI and significant reduction in peak heat release rate within the micro combustion calorimetry. Additionally, reprocessing trials showed, that in principal a recycling of such kind of ternary composites is possible to some extent.
Keywords: Cellulose, composite, PLA, flammability.

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Polymer Electrolytes: Prospects in Realizing Next Generation All-Solid Li-ion Batteries

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One of the key constituents in multi-component electrochemical systems is the '*electrolyte*'. It is understood that apart from all the other components, the device performance and life-time is dominated by the functioning and stability of the electrolytes under operational conditions. A long-standing goal in electrolyte research is the preparation of an ideal electrolyte that combines the processing characteristics of polymers and the ionic conductivity of low molar mass liquids. *Polymer electrolytes* contrast sharply compared to the usual electrolyte materials with respect to the mode of charge transport and the value of ionic conductivity; however, for electrochemical applications the flexibility offered by the PE is important. Coupled with high volumetric power densities, the volume changes in a cell during cycling can be easily accommodated without physical degradation of the interfacial contacts, thus allowing space-efficient battery designs. Though the PEs are projected to address multiple issues related to device performance, factors such as relatively low ionic conductivity, the ability of polymer electrolytes to operate with highly reactive electrodes such as lithium over a wider temperature range without deterioration in the charge capacity and electrolyte properties, the high interfacial electrode-electrolyte impedances are still a major technological challenge and far from practical realization.

Our group has been actively exploring the ambitious prospect to realize all-solid Li^+-ion rechargeable batteries, optimize solid polymer electrolyte matrices possessing ionic conductivity and electrochemical properties suitable for practical applications and probe the feasibility of paring these solid polymer electrolytes with commercial electrodes. The challenges involved in this amalgamation comprise not only the rational selection of materials, but also the design of device architecture and its successful fabrication. The goal is to demonstrate the competitive feasibility of such an electrochemical device coupled with elucidating the underlying mechanisms, cell performance validation, life-cycle analysis & stability. As a proof-of-the proposed concept, the preliminary results achieved have been particularly encouraging. The presentation would provide a brief overview on the role of polymer electrolytes in the prospective storage devices, the present status, bottlenecks and opportunities. Our continuing efforts towards the design and development of polymer / polymer-nanocomposite electrolytes along with the highlights of some encouraging results and future research directions would be discussed in the context of the identified gap areas.

Keywords: Lithium-metal batteries, lithium iron phosphate, polymer electrolyte, all solid-state devices, electrochemical stability.

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Polymer Engineering for Biomedical Applications - Material development for implants

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Abstract: Polymer engineering plays a crucial role in the development of advanced solutions for biomedical applications. Biocompatible and biodegradable polymers are of interest or even already used in fields such as tissue engineering, controlled drug delivery, implant technology, and medical diagnostics. By tailoring polymer structures, mechanical, chemical, and biological properties can be precisely adapted to meet specific medical requirements. In the presentation our recent results of the BioIMplant project, funded by M-ERA.NET, will be discussed. The project focuses on the design of advanced bioresorbable polymer composites reinforced with bioactive glass (BG) for osteosynthesis. These composites are engineered to degrade safely in the body, eliminating the need for secondary surgeries after bone healing, and to actively promote bone regeneration. BG is a well-known osteoconductive material that enhances bioactivity and mechanical strength. However, poor dispersion of BG within polymer matrices often leads to inhomogeneities that compromise performance. To overcome this, BioIMplant employs polymer interface engineering strategies-specifically, surface modification of BG using bifunctional compatibilizers. These modifiers enhance BG-polymer compatibility, improve dispersion, and enables the provision of bone growth-promoting bioactive glass at the site of regeneration. By engineering the polymer matrix and filler interface, the project targets composites with tunable degradation, mechanical performance, and biological functionality.

Results on the processability of the new composites using precision micro-injection molding and additive manufacturing will also be presented. These polymer processing methods can be used to produce complex, patient-specific implant geometries with controlled resorption rates and customized mechanical properties.

Acknowledgment:

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Keywords: bioresorbable, bioactive glass, implant material, injection molding, additive manufacturing

Biosynthesis of Mycelial Mass of *Ganoderma lucidum*: A Value-added Advanced Biopolymer

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Biopolymers are naturally derived polymers composed of multiple units, produced during the growth of living organisms (either plants, bacteria, or fungi), that are generally referred to as natural polymers. Biopolymers are basically classified into two categories: one derived from living organisms (polysaccharides and proteins) and the other produced from renewable resources through polymerization (polylactic acid) [1,2]. Moreover, it is reported that biopolymers possess enhanced and novel properties, such as improved mechanical properties, upgraded barrier properties, improved bioactivity, thermal stability, biocompatibility, and biodegradability, which need to be examined. Besides all those polymer properties, biopolymers sometimes have inherent advanced value-added properties (such as antiviral, anti-inflammatory, anti-cancer, and antibacterial) from a healthcare perspective. Hence, attention has been given to the synthesis of biopolymer from Ganoderma lucidum, a living organism commonly known as "Reishi" (Japan) or "Lingzhi" (China), recognized as a medicinal mushroom due to its bioactive compounds like polysaccharides and triterpenoids that contribute to its use as a health-promoting supplement [3,4]. In this work, emphasis has been placed on the optimization of production/biosynthesis of mycelial mass of Ganoderma lucidum in the presence of a suitable liquid culture medium (as shown in Figure 1), with 100 ml of medium in a 500 ml glass bottle under both shaking and stationary states at a temperature of 30°C, pH 5.5, and an incubation period of 15 days. Interesting results will be discussed during the presentation.

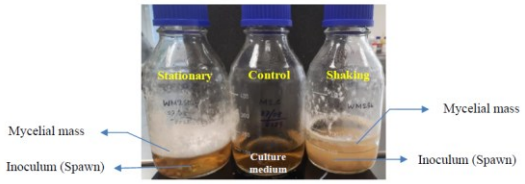


Figure 1–Biosynthesis of mycelial mass of *Ganoderma lucidum* in presence of liquid culture medium [5]

Keywords: Advanced biopolymers, biosynthesis, fungi, *Ganoderma lucidum*, mycelial mass

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Cellulose Nanocrystals-based Novel Functional Nanocomposites for Sustainable Food Packaging Applications

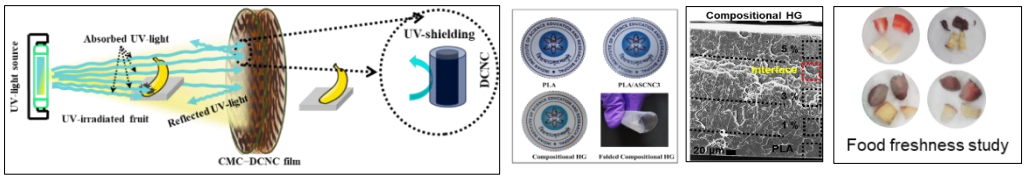
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There is a growing need for sustainable materials due to white pollution causing environmental concerns. Cellulose nanocrystals (CNCs) are sustainable and environmentally friendly nanomaterials and have received significant interest due to their outstanding mechanical, optical, chemical, and rheological properties. Herein, we developed mechanically robust, lightweight, and functional bioinspired polymer nanocomposites by combining surface modified CNCs with bio-based polymers following two bioinspired structural designs[1] such as: (i) bouligand structure and (ii) compositional gradient structure.

The bouligand ternary nanocomposites were fabricated via water-borne evaporation-induced self-assembly (EISA) process using polydopamine-modified cellulose nanocrystals (DCNCs) and sodium carboxymethylcellulose (CMC) as the hard and soft phases, respectively.[1,2] The CMC/DCNC-24 nanocomposites with the optimized PDA coating thickness and feed ratio exhibited the excellent mechanical strength (183 ± 36 MPa) and stiffness (15 ± 0.5 GPa) at 20% RH placing these materials among the top end of the CNC-based nanocomposites reported so far. In terms of functional properties, the CMC−DCNC films exhibited UV-shielding properties, free-radical scavenging ability, and water vapor transmission barrier properties suitable for packaging applications.[3,4]

Further, to address the brittleness of poly (lactic acid) (PLA) for flexible packaging, nanocomposites with compositional gradient architecture were fabricated using PLA and 3-aminopropyltriethoxysilane (APTES)-modified cellulose nanocrystals (ASCNC) via sequential deposition method. The gradient films showed better mechanical and thermal properties compared to pristine PLA, and PLA/ASCNC laminates and non-graded nanocomposites. In terms of functionality, the gradient films displayed transparency, low water vapor permeability, biodegradability, and a longer shelf life for perishable cut fruits, thus showing potential for flexible food packaging applications.[5]



Keywords: Bioinspired nanocomposites, Compositional gradient materials, Polydopamine, Cellulose nanocrystals, Food packaging film.

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Assessing Role of Hydrophilic Polymeric Scaffolds Towards Development of Electrodes for Green H_2 Production

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Avenues and systems capable of green H_2 production via water splitting applications is gaining momentum globally owing to its ability to address the energy challenges in a carbon neutral and environmentally sustainable manner. The key aspect of the technology is to devise electrodes and electrolyzers that can handle the energy efficiency of electrocatalytic water splitting process with adequate durability so that the cost of H_2 production is decreased below 2 $/kg of H_2. To contribute to this aspect, we have developed several durable electrode systems coated with nanocatalysts utilizing hydrophilic polymeric scaffolds as a key precursor. The resulting active multicomponent nanocomposite electrocatalyst systems display adequate activity and are instrumental in improving the energy efficiency of overall H2 production below 50 kWh/kg of H_2. The morphology of multicomponent system also displayed efficacy to resist harmful ions from reaching the active surface and enhance durability of the electrode for a sustainable period. Overall, the strategy demonstrated promise for further commercial implementation. The presentation will highlight some of our recent highlights and research outputs related to the above.

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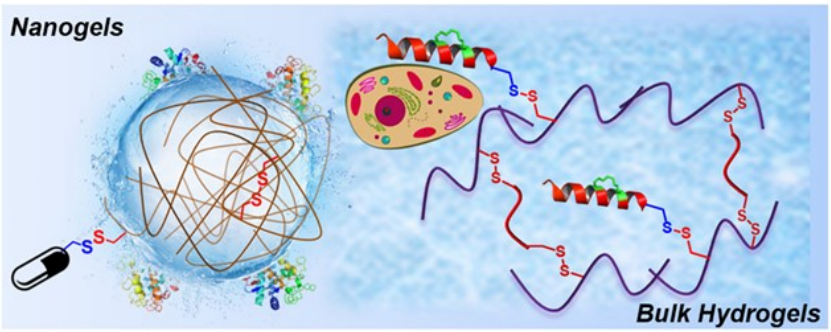
Redox-responsive Polymeric Materials: Tailoring Nano to Bulk Biomaterials for Biomedical Applications

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Stimuli-responsive polymeric materials—such as nanogels, microgels, and bulk hydrogels—offer versatile platforms for overcoming key challenges in modern diagnostics and therapeutics. Their ability to reversibly respond to external or internal stimuli enables precise control over material behavior and function. This presentation will describe our strategies for designing and fabricating novel thiol–disulfide exchange-based polymeric systems, encompassing nanogels, microgels, and bulk hydrogels (Figure 1). We employ diverse fabrication techniques, including self-assembly, microfluidics, and cryogelation, to produce materials with tunable responsiveness and functionality. Applications will be showcased in areas such as on-demand protein and cell capture and release, as well as stimuli-triggered delivery of therapeutic agents [1-3]. Overall, the talk will demonstrate how simple yet powerful organic transformations can be leveraged to engineer functional polymeric materials for a broad range of biomedical applications.



Figures 1 – Illustration of redox-responsive nanogels and bulk hydrogels.

Keywords: Stimuli-responsive, Redox-responsive, Hydrogel, Nanogel, Drug Delivery

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Functionalized Castor Oil-Pnipam Based Composite Hydrogel Film With NIR Shielding Ability For Thermoresponsive Smart Windows And Smart Curtains

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Near-infrared (NIR) radiation carries around 50% of the total solar light energy, which is a major reason for the heating of buildings. Due to this phenomenon and rapid climate change due to global warming, almost half of the total global energy consumption is targeted towards air-conditioning in buildings. As windows are considered, the least energy-efficient part of the buildings, it is necessary to develop thermoresponsive smart windows with high NIR shielding and tuned visible light transmittance to improve energy efficiency. But, maximizing the shielding of NIR radiation while retaining visible light transmittance is a challenge to be addressed in smart window applications. Herein, we have developed highly flexible and thermoresponsive copolymeric hydrogel films by incorporating NIR shielding nanoparticles for smart window applications. The thermoresponsive polymer poly(N-isopropylacrylamide (pNIPAM) exhibits broad transition temperature with high visible light transmittance below and reduced visible light transmittance above its lower critical solution temperature(LCST) respectively due to its optical phase transition from transparent to opaque state. The broad transition temperature of cross-linked pNIPAM hydrogel film can be precisely modified to a preferred LCST value through the copolymerization reaction. The incorporation of NIR shielding nanoparticles into the copolymeric matrix enhances the NIR shielding capability of hydrogel films. In this work, a thermo-responsive film of functionalized castor oil grafted pNIPAM copolymeric hydrogel was prepared by free radical copolymerization reaction, and different wt% of $Cs_{0.33}WO_3$ nanoparticles were integrated into the film to impart strong NIR shielding ability. The introduction of functionalized castor oil helps to fine-tune the LCST to a desired range which increases the practicability of the copolymeric hydrogel films as smart windows. The smart window fabricated with this composite hydrogel film shows good integral luminous transmittance, justifiable solar modulation ability, and significant thermal insulation performance. The highly reversible phase-changing nature of functionalized castor oil-pNIPAM copolymeric film with high NIR shielding ability of the $Cs_{0.33}WO_3$ nanoparticles has a greater significance in the development of energy saving, climate-adaptable smart windows, and flexible or foldable smart curtains.

Keywords: Castor oil-pNIPAM; $Cs_{0.33}WO_3$ nanoparticles; composite hydrogel film; NIR shielding; thermoresponsive; smart windows.

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From Tree to Thermosets: Greener Materials using Abietic Acid and Lignin

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The development of renewable thermosetting polymers is a central challenge for replacing petroleum-derived systems in high-performance sectors. This contribution highlights two advances based on forest resources, rosin and lignin, illustrating how underutilized biofeedstocks can lead to innovative materials for coatings, composites, and foams. In the first part, we report on rosin-derived epoxy thermosets. A key result is the design of Epoxidized Maleopimaryl Oleylamide (EMPOA), a novel bifunctional compound that uniquely combines both epoxy and anhydride moieties within the same molecular backbone. This dual reactivity enables versatile curing pathways, from epoxy homopolymerization to epoxy-anhydride copolymerization, and allows EMPOA to function either as a resin or as a co-hardener with other biosourced epoxies. Networks produced from EMPOA-based formulations exhibit high renewable carbon content and excellent anticorrosion performance, protecting aeronautic aluminium alloys for more than 1000 hours in salt-spray testing, surpassing conventional bisphenol A-based benchmarks. In the second part, we integrate lignin as a biofiller into isocyanate-free polyurethane formulations composed of CO_2-based poly(cyclic carbonate)s and diamines. These formulations, containing up to 30 wt% lignin, foam at 100 °C without external blowing agents. Moisture naturally present in the biofiller partially hydrolyzes the cyclic carbonates, releasing CO_2 as the blowing agent. Beyond initiating foaming, lignin also contributes as filler, stabilizer, and flame-retardant promoter, enabling the production of rigid foams with competitive performance and inherent fire resistance.[1] Together, these studies demonstrate how rosin and lignin can be harnessed not only as renewable substitutes, but as sources of unique chemical functionalities. They underline the potential of biosourced thermosets to combine originality in molecular design with true industrial relevance.

Keywords: Biosourced thermosets, Rosin, Epoxy-anhydride copolymerization, Isocyanate-free polyurethanes, Lignin valorization.

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A Multifunctional MOF-based Strategy for Synergistically Enhanced Durability and Performance in Next-generation PEMFC Membranes.

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In the era of green hydrogen, proton exchange membrane fuel cells (PEMFCs) have gained significant attention as sustainable energy sources due to their ultra-low emissions characteristics, high power conversion efficiency, and moderate operating conditions. However, the overall performance and durability of PEMFCs are heavily depend on the proton exchange membranes (PEMs). While PFSA-based membranes such as Nafion and Aquivion remain the benchmark but suffer from low proton conductivity at elevated temperature and low relative humidity which hinder practical applicability for widespread adoption. Incorporation of a tunable porous framework to prepare a mixed matrix membrane proved to improve its performance. As, an efficiently designed 1D Co(II)-coordination polymers offers a promising strategy to enhance its performance up to 82%. But despite these advantages they pose several other limitations due to their high accruing cost and environmental persistency. In search of an alternative, sulfonated poly(aryl ether) based membrane gained a significant acclaim due to their ease of sulfonation, excellent electrochemical properties, high thermo-mechanical stability, and cost-effectiveness. Nevertheless, they also suffer from oxidative degradation and an inherent trade-off between proton conductivity and mechanical durability. Not only that they are much more prone to oxidative degradation in regards to the PFSA based membrane. To resolve these, we explored 2D fishbone-type network of uncoordinated carboxylic acid group tethered Co(II)-metal organic framework, which not only improve its performance but effectively mitigate the trade-off dilemma, reduce fuel-crossover and thus improving the performance and durability of the PEMs. However, the scalability and cost of the framework remain bottlenecks. To overcome these challenges, we further explored a scalable design based on zirconium–cerium bimetallic MOFs functionalized with amine linkers. The Zr nodes provide thermal and chemical stability, while immobilized Ce species act as efficient radical scavengers to suppress oxidative degradation. Additionally, the amine functionality promotes acid–base interactions, thereby enhancing proton transport pathways. The resulting composite membranes demonstrated improved durability, suppressed radical-induced degradation, and superior fuel cell performance compared to pristine sulfonated polymers, coming up to commercial Nafion. Thus, this work highlights a practical, scalable, and multifunctional MOF-based strategy to synergistically enhance both the performance and durability for next-generation PEMFC membranes.

Keywords: Proton exchange membrane fuel cell, Hydrogen-bonded MOF, composite membranes; boosted proton conductivity; oxidative stability.

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Advancing Therapeutics through Polymeric Drug Delivery Systems: Innovations, Challenges, and Future Directions

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Polymeric drug delivery systems have revolutionized the landscape of pharmaceutical sciences by offering versatile platforms for controlled, targeted, and sustained release of therapeutic agents. These systems utilize biocompatible and biodegradable polymers—both natural and synthetic—to overcome limitations associated with conventional drug formulations, such as poor solubility, rapid clearance, and systemic toxicity. Recent developments in polymer engineering have enabled the design of stimuli-responsive carriers, including pH-sensitive hydrogels, temperature-responsive micelles, and enzyme-degradable nanoparticles, which allow site-specific drug release and improved therapeutic efficacy.

This presentation highlights the formulation strategies, characterization techniques, and clinical translation of polymeric drug delivery systems. Emphasis is placed on nano- and micro-scale carriers, polymer-drug conjugates, and long-acting injectable depots. Case studies from oncology and infectious diseases illustrate the potential of these systems to enhance bioavailability, reduce dosing frequency, and improve patient compliance. Furthermore, the integration of polymeric carriers with targeting ligands and imaging agents is discussed in the context of theragnostics and personalized medicine.

Challenges such as polymer-drug compatibility, scale-up, regulatory approval, and long-term stability are critically examined. The talk also explores emerging trends including hybrid polymer systems, 3D-printed drug delivery devices, and AI-assisted formulation design. By bridging material science with pharmacology, polymeric drug delivery systems are poised to redefine therapeutic paradigms across multiple disease areas.

Keywords: Polymeric drug delivery, controlled release, biodegradable polymers, nanocarriers, personalized medicine

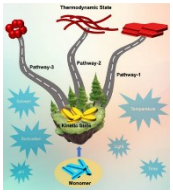
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Exploring Pathway Complexity in Supramolecular Self-Assembly of Chromophore–Appended Peptides and Amino Acids for Functional Property Modulation

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Supramolecular self-assembly is a fundamental process in nature, enabling the formation of diverse nanostructures in living systems through the subtle interplay of noncovalent interactions. Inspired by nature's design principles, scientists have sought to mimic these processes using artificial building blocks to construct functional nanostructures. Among these, amino acids and peptides stand out as highly promising candidates owing to their inherent biological relevance, biocompatibility, biodegradability, and remarkable structural tunability. Conjugation of chromophoric units to these biomolecular scaffolds further enhances their functional properties, opening avenues for applications in fields ranging from bioelectronics to biomedicine. A central theme of our research is understanding how control over the self-assembly process governs the morphology of the resulting nanostructures and, consequently, their material properties. In one of our studies, we explored the supramolecular self-assembly of a naphthalene diimide (NDI)-conjugated peptide system. By carefully modulating the assembly pathways, we uncovered pathway complexity: kinetic trapping led to spherical nanoparticles and short nanorods, while thermodynamic equilibration produced long, entangled nanofibers with distinct chiroptical switching behavior. Strikingly, electromechanical investigations revealed that the kinetic products were piezo-inactive, whereas the thermodynamically stable nanofibers exhibited pronounced piezoelectric activity. This finding underscores how morphology and molecular packing dictate piezoelectric responses, highlighting the importance of supramolecular pathway control in designing peptide-based piezo-biomaterials. In a related study, we examined the assembly behavior of NDI-appended amino acids to further elucidate the role of pathway complexity in governing nanostructural and functional outcomes. The kinetic state yielded spherical nanoparticles with active chiroptical properties, arising from the helical arrangement of the molecules. In sharp contrast, the thermodynamic state formed two-dimensional nanosheets that were chiroptically inactive due to achiral molecular packing. Surprisingly, electrical conductivity studies revealed an unconventional phenomenon: the kinetically trapped state exhibited measurable electrical conductivity, whereas the thermodynamic nanosheets were electrically insulating, likely due to disordered packing in the stable state. Such behavior—where conductivity is associated with the kinetic rather than the thermodynamic state—is rare and demonstrates how subtle changes in molecular organization profoundly influence electronic properties. Collectively, these findings provide a compelling demonstration of how pathway-dependent supramolecular self-assembly can be harnessed to regulate nanostructural morphology and functional properties such as chirality, piezoelectricity, and conductivity. By carefully designing chromophore–peptide and amino acid systems and exploiting pathway complexity, it becomes possible to generate tunable biomaterials with unique properties tailored for specific applications.



Keywords: Pathway complexity, Supramolecular self-assembly, Peptide and Amino acids, Functional Properties.

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Functional Polymer Materials for Passive Radiative Cooling Applications

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Increasing global temperature led to an increasing demand for cooling. This necessitates developing sustainable strategies that can help reduce energy for cooling [1]. Passive radiative cooling is a strategy that can emit the heat as thermal radiation into outer space, bypassing the greenhouse effect. At the center of passive radiative cooling lies the functional materials that can selectively emit in the atmospheric transparent window in the mid-infrared (mid-IR) region of 8-13 μm. An ideal passive radiative cooling material should have near unity emissivity in the mid-IR window, near zero absorptivity, and near unity transparency or reflectivity in the solar irradiation window (0.3- 2.5 μm) [2,3]. Many materials can be tuned to meet these requirements to a certain extent, e.g., polymer, metal oxides, and dielectric materials. However, the existing challenges are to create a passive radiative cooling material that is sustainable, scalable, inexpensive, and can result in angle-independent cooling [1]. We are designing biopolymer-based sustainable polymer composites with a hierarchical structure that can potentially address these challenges. The sustainability and scalability aspects can further assure widespread application of these functional materials on various surfaces for passive cooling. For example, on solar cells to prevent their overheating, or on the building rooftops to cut the energy costs of the cooling.

Keywords: Passive cooling, radiative cooling, functional materials, polymer composites.

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Polyurea coatings for mitigation of blast and ballistic effects

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Elastomeric spray-on coatings have emerged as excellent retrofit materials for strategic applications, particularly for **blast mitigation and ballistic protection**. Among these, **polyurea** is noteworthy for its ease of application, rapid cure, strong adhesion to diverse substrates, and exceptional balance between tensile strength and elongation. When subjected to blast or impact, polyurea undergoes large reversible deformation, effectively absorbing and dissipating the energy generated by dynamic loads.

Polyurea is formed by the rapid reaction of an **isocyanate** with an **amine**, typically supplied as a **two-component system**: *Side A* (isocyanate) and *Side B* (amine). Achieving optimal mechanical performance requires precise formulation of the amine resin, incorporating a tuned blend of long-chain amine, crosslinker, and chain extender. In this work, we report a **two-component system** comprising an isocyanate prepolymer and a tailored amine blend, which reacts to form a seamless coating on concrete and metallic substrates. The coating properties were tuned by varying the composition of the amine resin blend.

The **blast mitigation performance** of the developed polyurea coatings was evaluated using shock tube experiments. A marked reduction in damage was observed when the coating was applied to the tension face of concrete tiles. While uncoated tiles experienced extensive fragmentation at 50 psi peak pressure, coated tiles with a 6 mm polyurea layer withstood pressures approaching 90 psi. Additionally, **polyurea nanofibers** were fabricated via electrospinning to explore potential enhancements in interfacial and energy dissipation behavior.

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Editorial Insights: A Wiley Perspective

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Wiley is a global leader in scientific publishing with a legacy of over 200 years and a comprehensive global mission to enable discovery, power education and shape the workforce. With a portfolio of world-class journals spanning fundamental and interdisciplinary research, Wiley delivers trusted, high-quality content that drives progress and earns recognition worldwide.

Along with its enriched repertoire of journals, Wiley's polymer portfolio is one of the most diverse and strategically curated in academic publishing domain. It encompasses titles that cover fundamental polymer science, synthesis, polymer physics, biomedical applications and functional materials related research. As interest in polymeric materials continues to surge, driven by their versatile molecular structures and transformative potential in materials science, medicine, energy, and sustainability, Wiley is committed to providing researchers with the recognition and inspiration they need to push boundaries and shape the future.

This session will present Wiley as a cornerstone of global scientific publication, highlighting its rich legacy and unwavering commitment to advancing research along with a special focus on Wiley's distinguished Macromolecular portfolio. The discussion will also showcase Wiley's active engagement with the vibrant community of Indian polymer researchers, underscoring collaborative opportunities and pathways for impactful contributions. Participants will gain exclusive insights from the editor's desk, including practical guidance on how to craft impactful manuscripts and successfully publish in Wiley journals. In addition, as AI-driven generative language models continue to transform scholarly communication, current discussion will explore their expanding impact and present best practices for ensuring the ethical and responsible integration of AI tools in peer-reviewed scientific publishing.

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Sodium Alginate/Polyvinylpyrrolidone/Lapatinib-loaded Zr-Metal Organic Framework: Examination of Drug Release for Oral Delivery Applications

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The advancements in drug delivery systems have significantly modified drug administration protocols to ensure targeted delivery with minimal side effects (1,2). Innovations in the field of polymer-metal organic frameworks can markedly improve drug stability and controlled release properties (3,4). In this work, a drug delivery system based on a zirconium metal organic framework (Zr-MOF), sodium alginate (SA), and polyvinylpyrrolidone (PVP) has been generated and characterised. Lapatinib, an oral anticancer drug used to treat breast cancer, has been incorporated within the pores of a Zr-MOF. Although lapatinib can specifically inhibit HER2 receptors and cancer cell proliferation, it suffers from some constraints due to its poor oral bioavailability and side effects. To address these issues, a drug-loaded Zr-metal organic framework has been embedded in a sodium alginate (SA)/polyvinylpyrrolidone (PVP) polymer matrix. This combination has been found to modulate drug release characteristics, promote pH-responsive targeted drug delivery, increase stability, enhance mechanical properties, improve hydrophilicity, and enhance the biocompatibility (5). The findings confirm that the system can intrinsically prevent premature gastric release, emphasizing its potential to achieve high therapeutic effects at lower doses with reduced side effects. Biocompatibility assays indicated over 94% viability in the relevant cell lines after 24 and 48 h, indicating the favorable cytocompatibility of the composites. Overall, this composite platform provides controlled, sustained, and site-specific release of lapatinib, which could potentially enhance oral bioavailability, reduce dosage frequency, and systemic toxicity.

Key words: Zr-MOF, Sodium Alginate, Polyvinylpyrrolidone, Lapatinib, Drug release.

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Conducting Polymer Hydrogels for Energy Harvesting and Sensing Applications

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Conducting hydrogels, represent a promising class of smart materials due to their unique combination of high water retention, biocompatibility, and tunable electrical conductivity. The present study focuses on the development of PANI/PVA conducting hydrogels via in-situ chemical polymerization and freeze-thaw cycles, with optimized compositions to balance conductivity and gel integrity towards a range of applications. It is possible to tune electrical conductivity and structural integrity by varying the composition of PANI and PVA. The hydrogel shows an excellent material as a supercapacitor electrode material with ~95% capacity retention after 1000 cycles [1]. Further investigation into the effect of repetitive freeze-thaw (FT) cycles evealed enhanced microstructural features, resulting in improved sensitivity (94.7%) for NH_3 gas detection at 100 ppm, with an LOD of 1 ppm [2]. The sensor exhibited rapid response and recovery times (25 s and 10 s, respectively), along with selectivity towards NH_3, NO_2, CO_2, and certain volatile organic compounds (VOCs). We have also explored the effect of incorporating metal nanoparticles (Platinum nanoparticles) into the PANI/PVA matrix for biomolecule sensing applications. A Pt-NPs@PANI/PVA hydrogel sensor (Figure 1) exhibited enhanced electrical conductivity and responsiveness in both deionized water and artificial tear fluid for glucose detection, achieving a sensitivity of 7.364 µA/dec within a linear range of 1 µM–30 mM and an LOD of 0.44 µM [3]. Non-enzymatic glucose sensing was further investigated using rGO@PANI/PVA hydrogels, where varying rGO content improved mechanical strength and performance in a field-effect transistor (FET) based sensors.

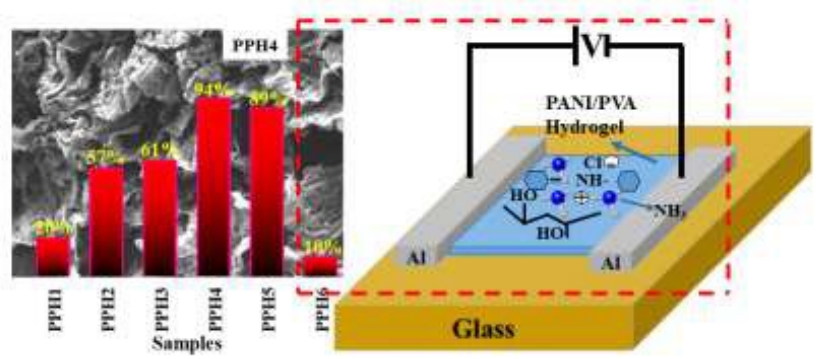


Figure 1: Pt@PANI/PVA conducting hydrogels for sensing applications.

Keywords: Conducting hydrogels, PANI/PVA, Supercapacitor, Sensing.

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High-Performance Polymers in the Circular Economy: Recycling Strategies and Innovations for Advanced Materials

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Syensqo Specialty Polymers is a market leader in delivering advanced polymer solutions that drive sustainable mobility, lightweighting, and energy efficiency. Our broad portfolio—including high-performance polymers such as PEEK, PVDF, PES, and others—enables innovative applications aligned with global sustainability goals. These materials are integral to sectors such as batteries, e-mobility, renewable energy, the hydrogen economy, water purification membranes, connectivity, and life sciences.

A current focus of our research is polyvinylidene chloride (PVDC), a polymer renowned for its exceptionally low permeability to oxygen and water vapor. PVDC's ability to retain barrier properties even under demanding conditions (high humidity), combined with its processability, has established it as a preferred barrier layer in high-performance packaging films. As the recyclability of packaging materials becomes increasingly critical to reducing plastic waste and enhancing sustainability, our research explores multiple approaches to improve the circularity of high-performance films. Both mechanical and advanced recycling technologies are being investigated to address the challenges of the circular economy and to promote sustainable solutions in packaging.

This lecture will highlight Syensqo's latest advancements in specialty polymers, with a particular emphasis on PVDC research and the development of recycling strategies to support a more sustainable future.

MXene-Polyimide Composite: A potential coating material for the protection of steel substrate

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2D nanomaterials such as graphene, boron nitride, and molybdenum disulfide composites are known to have anti-corrosion properties. However, interactions with saline environments can significantly influence this property. Here, the superior anti-corrosion properties of a 2D MXene composite coating derived from the MAX phase are obtained over mild steel. MXene-polymer interactions serve as an efficient electron donor for the corrosion pathway, where electrons modify oxygen-containing functional groups on MXene surfaces to generate reactive hydroxide. Therefore, the cathodic electrochemical reaction due to oxygen reduction is significantly controlled by MXene, as confirmed by the reduced cathodic slope in the Tafel polarization measurements. The lack of an anti-corrosion effect in the pure polymer film of 10±2µm on mild steel was addressed by MXene polyimide composite coating, by electrochemical studies having an impedance of 2.18×10^{7} $\Omega.cm^{2}$ after 360 hours of immersion in 3.5% NaCl medium. Including MXene improves the corrosion resistance and increases the film's adhesion strength, contact angle and conductivity to 1.17×10^{-3} S/cm of MXene polyimide nanocomposite coating. Lastly, a mechanism has been proposed to understand the anti-corrosion behaviour of MXene in a polyimide matrix.

Keywords: MXene, Corrosion, Mild steel, Polyimide, Coating.

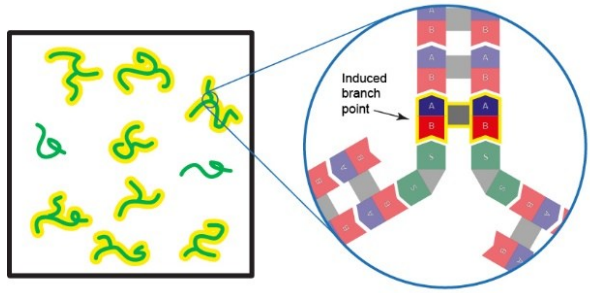
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Branched Supramolecular Copolymers

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Supramolecular polymers are exceptional polymers: they exhibit similar scaling laws and non-Newtonian rheology like conventional polymers, yet the non-covalent interactions holding their backbone impart them with unique properties, such as the ability to dynamically change their lengths with a change in environmental conditions and the possibility to completely de-polymerize into the original monomers. Self-healing and recyclability are inherent to their nature.
Interestingly, the aspect of branching, which fundamentally influences polymer properties, remained largely unexplored so far. Theoretical treatment and most rheological studies concentrated either on linear/cyclic supramolecular chains or on hyperbranched architectures.
The presentation will describe the design of supramolecular comonomers that induce branching in the supramolecular chain, some non-trivial experimental observations, and an adaptation of the classical polymer theories on branching to supramolecular polymers that was used to explain the results.[1] The insights gained from this study enable tuning the properties of supramolecular polymers not only by concentration, temperature, and pH, but now also by the supramolecular chain architecture.[2] This may lead to the development of sophisticated smart materials.



Keywords: Supramolecular polymers, diffusion-ordered NMR spectroscopy, Viscosity, Branching.

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Siloxane-based Augmented Hemostatic Treatments

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There is an urgent need to develop effective hemostatic treatments that can stanch blood loss while being easily applicable at the point of care [1]. Traditional methods, such as gauze and tourniquets, have shown limited efficacy, and as such, the fabrication of novel hemostatic materials has advanced tremendously in the last decade. Although there has been considerable success in recent years in engineering novel hemostats, developing an effective hemostatic material that is biocompatible, fast-acting, and has hassle-free application and removal, while being a cost-effective, viable option, remains a challenge. The objective is to provide the patient with a means to rapidly arrest bleeding from trauma-related wounds in a manner superior to those currently available, within a few minutes [2]. Herein, we present a unique hemostatic bandage system, SILFOAM, which we have developed for its hemostatic efficacy with different blood-flow rates using a non-invasive model that aims to provide an easy, fast, and economical route to test hemostats before *in vivo* studies [3]. The formulation of our bandage system comprises two parts, A and B, which consist of a homogenous mixture of siloxane A, a silicone-curing catalyst, inorganic oxides, and a non-ionic surfactant. Similarly, Part B consists of a homogenous mixture of siloxane B, an activator, silica, and a surfactant. The two components react in situ to form a self-conforming, flexible, sponge-like foam that conforms on and around the wound, thereby acting as an artificial blockage by creating an autogenous pressure on the site to arrest bleeding. When these two parts interact, activator molecules are rapidly decomposed to form oxygen or carbon dioxide gas, which acts as a blowing agent, thereby foaming the siloxane matrix to form the sponge-like foam in less than a minute. Various inorganic oxides have been tested at multiple concentrations to determine the optimal composition for both expansion and temperature, thereby reducing possible embolism risks. Studies on mechanical durability, thermal properties (temperature), surface adhesion, hydrophobicity, rheology, closed porosity through imaging, spatiotemporal analysis, and additional in vitro assays will also be presented. Bleeding efficacy for this material and other hemostats was tested using a noninvasive torso hemorrhage model (manikin) equipped with an electronic bleeding controller. We are currently developing a new variant using calcium oxide to enhance the biocompatibility of the sponge and introduce bioactive Ca^{2+} release, as well as incorporating TRAP-6, a synthetic platelet-activating peptide, to accelerate clot formation through targeted biochemical signaling further. By integrating both physical tamponading and biochemical platelet activation, these efforts aim to address key limitations in current trauma dressings. These unique strategies to develop hemostatic dressings that contain gas-generating blowing agents are a convenient approach to create a biocompatible, hemostatic bandage system that can treat different types of wounds, including pressure sores, ulcers, and recalcitrant open wounds.

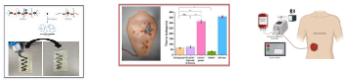


Figure 1 – Inorganic Oxides and Peptide-integrated Siloxane Hemostats.

Keywords: Polymer, Wound-healing, Hemostasis, Noninvasive, Antibacterial, Peptide.

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Radiation assisted designing of superabsorbent/adsorbent to combat water pollution

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Water is contaminated in various ways, such as oil spills or post-use discard of various kinds of oils and oily liquids by industries. These oil/oily liquids are normally chloroform, bromoform, TBB, TBP, mobile, kerosene, diesel and organic solvents such as liquid alkanes, alkynes, etc. These impact the water purity, which affects our day to day life, cultivation, human lives, marine life etc in many ways. For this purpose, a cotton based superhydrophobic/superoleophilic superabsorbent is produced with the help of radiation assisted chemical modification. The surface roughness in sub-micron/nano scale is generated along with the reduction of surface energy by attaching long chain hydrocarbon molecules, which are of low surface energy. Three such super-absorbents namely cotton, jute fabric and PU sponge are modified in the microscopic scale, which manifests properties macroscopically. These superabsorbents absorb the above mentioned oily liquids instantaneously from aqueous system. Moreover, besides the above mentioned liquids, some solids such as micro plastic, nano plastic and dispersed dyes also pollute the water in a big way. Now, if some oils are added into microplastics containing water, plastic being hydrophobic, is dispersed immediately into oily phase. Now, if this oily phase is absorbed, plastic is removed. In this way, dyes also can be removed by super-hydrophobic super-absorbents. Another way of removing dispersed dyes is using adsorbent, which can adsorb dyes. For removing dispersed dye various kinds of (fibrous, porous) adsorbents are prepared by attaching various special groups to the fibrous (Flax fibre) and porous foam (PU Sponge) substrates by radiation. These can adsorb dispersed dyes up to 20 mg and 35mg per gm successively. In this way, such pollutants are eliminated from the water. These are very potential materials to combat water pollution.

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Microstructure of Emulsion Polymers

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The microstructure of emulsion polymer particles is widely recognized as a critical factor influencing the properties and performance of latex-based materials[1]. Published studies have shown that key features such as particle size distribution, internal phase morphology, and crosslink density can profoundly affect film formation, adhesion strength, durability, and other end-use properties of polymer coatings[2]. For example, early work by Sheetz demonstrated that the way latex particles coalesce during drying directly impacts the continuity and integrity of the formed film[3]. Subsequent reviews and texts have reinforced that a thorough understanding of these microstructural attributes is essential for optimizing formulations in paints, adhesives, and other waterborne applications[4]. This consensus in the literature underlines the importance of studying emulsion polymer microstructure to improve coating performance and to guide the development of advanced materials[5].

In this work, we present a detailed investigation of **vinyl acetate-**based and **styrene-acrylic** emulsion polymers, elucidating how their microstructural characteristics correlate with the performance of resulting paint films[6]. Using a combination of techniques such as microscopy, GPC, and NMR, we characterized these latex systems extensively. Our findings reveal a correlation between the emulsion polymer's microstructure and the properties of dried paint films formulated from them: variations in particle architecture and preparation method translated to measurable differences in film uniformity, adhesion, and durability. These results highlight the pivotal role of microstructural control in designing high-performance emulsion polymers for coating applications.

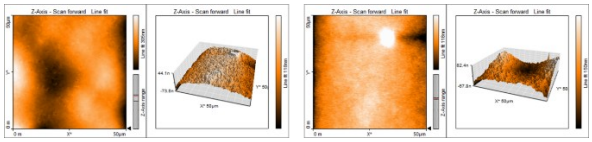


Figure 1: 2-D and 3-D AFM images of core-shell polymers. The left two are the images for a one-pot synthesis emulsion films, whereas the right two are the corresponding images for their two-pot counterpart. Two-pot means that the emulsion containing only the core was cooled to room temperature and stored for a few days and then a shell was formed by reinitiating the polymerization by using the core polymer particles as the seeds/nuclei.

Keywords: Emulsion, microstructure, paint film, surface morphology.

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Advanced biomaterials for biomedical applications

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Bioactive components derived from plants and animals are being researched for biomedical uses because they are renewable, compatible with living organisms, and environmentally friendly. For tissue regeneration, drug delivery, and cell proliferation, various polymeric materials are being designed and developed to fulfill specific requirements. However, there is always a potential need for innovations to improve the properties and accelerate the efficiency. Hence, there is constant research for the development of advanced materials.

In our lab, we aimed to develop polymeric materials using bioactive components such as neem oil, curcumin, and albumin. These bio-components have essential functions suitable for biomedical applications. Although studies exist on these components, the scientific challenge is engineering materials for specific uses. We synthesized antiviral and antibacterial polymers and oligomers using neem oil and curcumin and designed nanomaterials such as nanofibers and nanoencapsulates. We examined these respective materials for tissue regeneration and targeted them for cancer therapy. Egg albumin was functionalized to increase hydrophilicity and enhance biocompatibility. Blends of it was developed as a film, and its physicochemical properties were studied to evaluate its potential for wound healing. Pre-clinical studies of the materials confirmed their suitability for wound healing and targeted cancer therapy.

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Minimalistic Supramolecular Polymers for Maximal Catalysis: Lessons from Nature's Enzymes

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Enzymes achieve remarkable catalytic efficiencies owing to their intricate folding and precisely organized active sites. Yet, limitations such as instability, high production costs, and difficulties in recovery constrain their industrial use. Minimalistic peptide- and amino acid–based supramolecular polymers provide a sustainable and tunable alternative by forming ordered fibrous networks that emulate enzymatic microenvironments. These supramolecular polymeric fibers not only furnish high surface area and dynamic binding pockets for substrate recognition but also facilitate efficient electron/ion transport, thereby playing a pivotal role in catalysis. Inspired by natural enzymes, we developed two complementary biomimetic supramolecular polymeric hydrogel systems. A histidine-functionalized dipeptide hydrogel exhibited hydrolase-like activity, with molecular dynamics simulations elucidating its gelation pathway and substrate recognition features.[1] Upon coordination with Zn^{2+} or Cu^{2+}, the supramolecular fibers reorganized into metalloenzyme mimics, effectively catalyzing CO_2 hydration (carbonic anhydrase-like) and phenol/catecholamine oxidation (laccase-like). In parallel, an amino acid–derived hydrogel from Fmoc-tryptophan facilitated p-nitrophenyl acetate hydrolysis.[2] Hybridization with graphene quantum dots enhanced both catalytic efficiency and mechanical strength, while incorporation of gold nanoparticles imparted dye-degradation functionality. Encapsulation within alginate beads further improved recyclability, porosity, and operational ease. Collectively, these supramolecular polymer–based hydrogels highlight the synergistic role of fibrous assemblies in enabling reusable, versatile platforms for biocatalysis, environmental remediation, and sustainable chemical transformations.

Keywords: Peptide, Amino acids, hydrogels, enzymes.

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Lignocellulosic Biopolymers to Performance Materials and Product Showcase: Sustainable Solutions in Composites, Adhesives and Coatings

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As industries seek greener alternatives to conventional plastics, lignocellulosic biopolymers such as lignin, cellulose, and hemicellulose offer a renewable and underutilized resource. This work demonstrates how these natural materials can be transformed into advanced composites, adhesives, and coatings capable of replacing plastics in demanding applications while meeting high-performance requirements. By modifying the chemistry and structure of lignocellulosic biopolymers, we achieved materials with improved strength, toughness, and adhesion. Kraft lignin/polyurethane composites adhesive exhibit enhanced mechanical performance, bioactivity, and wet adhesion. Nano lignin/nanofibrillated cellulose hybrids provide superior ductility and toughness. Functionalization with sulfanilic acid or poly(itaconic acid) improves compatibility, UV resistance, and sustainability of wood adhesives and functionality of the composite, while hybrid materials of nanocellulose enhance hydrophobicity, durability, and overall performance. Natural fiber reinforced composites, such as flax–epoxy systems with thermoplastic interfacial toughening, demonstrate improved impact resistance and enhanced interfacial strength. These developments create high-performance alternatives to conventional plastics across applications such as sustainable wood products, packaging, automotive components, and construction materials.

Overall, this work highlights the potential of lignocellulosic biopolymers for creating sustainable, high-value composites, adhesives, and coatings. By valorizing natural biomass into materials suitable for plastic replacement, we demonstrate that environmental responsibility and industrial performance can be achieved simultaneously, paving the way for a more sustainable materials landscape.

Keywords: Lignocellulosic biopolymers, Lignin, Natural fiber, Bio adhesives, Bio composite.

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Ambient Electrochemical Synthesis of Green Ammonia, Urea, and Nitric Acid: Bridging Fundamentals to Sustainable Applications

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Fertilizers, rich in macronutrients like nitrogen, phosphorus, and potassium, are critical for global agriculture. Among these, fixed nitrogen is often the most significant limiting factor for plant growth, making the efficient synthesis of nitrogen-based fertilizers; such as ammonia, nitrate, and urea, absolutely essential.

In India, the escalating demand for these fertilizers, driven by agricultural expansion and urgent food security needs, presents a growing challenge. Currently, India heavily relies on imported raw materials and fossil fuels for fertilizer production, leading to considerable economic strain and environmental concerns. To address this, promoting vital import substitutes like ammonia, urea, nano-fertilizers, and nitric acid is paramount. India's Atmanirbhar Bharat (self-reliant India) initiative specifically emphasizes developing indigenous technologies for sustainable fertilizer production. Adopting renewable energy-based chemical processes can dramatically cut carbon emissions, reduce energy consumption, and lessen import dependency, thereby ensuring long-term agricultural productivity and environmental sustainability for the nation's burgeoning population.

Our laboratory has made significant strides in this direction, developing sustainable electrocatalytic methods for producing green ammonia, green urea, and nitric acid under ambient conditions. These innovative processes leverage metal phthalocyanine based electrocatalysts and are protected by robust intellectual property rights. We have successfully completed field trials for both green ammonia and green urea synthesis, demonstrating their high efficiency and environmental benefits.

Further advancing these solutions, we have already completed the technology transfer and licensing for pilot-scale green ammonia production in collaboration with a multinational company. Additionally, we have initiated the technology licensing process for green urea production, crucially utilizing CO_2 in partnership with industry. These efforts directly support India's vision for clean, self-reliant, and energy-efficient chemical manufacturing.

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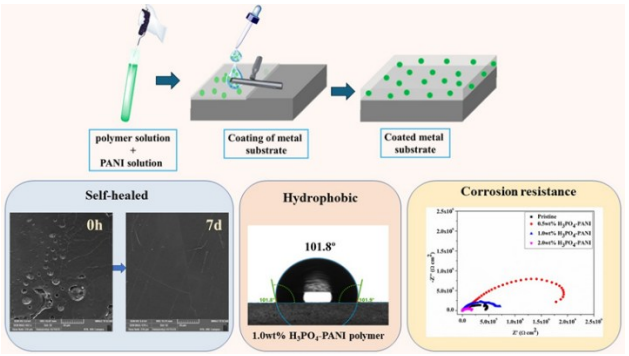
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Development of Polyaniline and Polystyrene-co-hexamethylcyclotrisiloxane Composite Coating for Anti-corrosion Application on Copper Substrate

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This research began with the aim of developing a cost-effective anti-corrosion polymer composite coating that can be easily applied to copper substrates. Copper is commonly utilized in a variety of electronic applications, sculptures, and industrial pipelines due to its mechanical strength and excellent electrical and thermal conductivities. However, it tends to corrode over time, particularly in marine and industrial environments. A transparent anti-corrosion coating will help maintain the underlying copper color and luster by preventing the penetration of corrosive ions such as chloride, sulfide, and sulfate. To achieve this objective, a copolymer of styrene and hexamethylcyclotrisiloxane was synthesized and thoroughly characterized to understand its structure-property relationship. The developed copolymer demonstrated excellent barrier resistance during both qualitative and quantitative anti-corrosion tests over a period of 7 days. To further enhance its anti-corrosion properties, a composite coating was created using the newly synthesized polymer combined with different acid-doped polyaniline (PANI), which serves as redox barrier additives. Electrochemical impedance spectroscopy (EIS) measurements indicated that the composite coatings with 1 wt% PANI-H_3PO_4 were the most effective, showing an impedance value ($|Z|$ at 0.01 Hz) on the order of 10^5 Ω·cm² after 7 days of continuous immersion in a 3.5% NaCl solution. Field emission scanning electron microscopy (FESEM) images of this composite coating clearly revealed its self-healing properties. In contrast, other acid-doped PANI composites exhibited significantly poorer performance compared to the same thickness of the pristine polymer coating. The better compatibility of PANI-H_3PO_4 redox additives within the polymer matrix enhances the anti-corrosion resistance of the composite coating. Furthermore, this specific PANI additive generates self-healing properties that allow the coating to recover from cracks even when continuously submerged in a corrosive environment for 7 days.



Keywords: Copolymer synthesis, Polymer coating, Composite coating formulation, Redox additives, Anti-corrosion coating.

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Applications of Polymer Science in FMCG Industry Translating Polymer Science to Functional Products: From concept-to-commercialization

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The applications of Polymers and Polymer Science in FMCG Industries is vast and ranges across their use in Home Care and Personal care products, such as in Detergents, Soaps, Shampoos and Dish Wash Liquids, to Foods, where there is an ample use of various biopolymers for structuring and rheology modification of Chocolates, Bakery Products and Snacks, and finally their ubiquitous application for Packaging of FMCG products.

A key focus area of our work is around polymer-based core-shell microencapsulation to ensure stability and controlled release of ingredients that go in to various product chassis, such as, use of microencapsulates to stabilize fragrances in highly acidic Toilet Cleaners[1]; stabilization of enzymes in high alkaline detergent formulations and protection of various functional active ingredients via microencapsulation in acidic beverage chassis. Our present work focuses on use of microencapsulation to stabilize a bioactive molecule in acidic beverages, such as in fruit juices. In this context, we will further discuss the life cycle of a technology from concept-to-readiness for commercial production.

In the context of the application of core-shell encapsulation in beverages, we have explored the well-known use of GLP-1 as a master regulator of blood glucose levels. It is further known in the literature that addition of the bioactive, L-glutamine stimulates the release of GLP-1 (Glucagon-Like Peptide-1). This in turn helps lower blood sugar levels[2] which show a spike upon ingestion of sugary beverages. However, L-glutamine is known to be unstable at acidic pH as in beverages, thus leading to negligible to nil bioactivity of this ingredient by the time it reaches it's point of action due to degradation. To address this challenge, our present work uses an emulsion system followed by core-shell encapsulation using specific biopolymers to encapsulate L-glutamine, such that it is protected from the surrounding acidic environment thus keeping it stable in the acidic beverage[3]. The glutamine which is in the protective shell is released in a controlled manner upon reaching the intestine where the polymeric shell undergoes disintegration due to a pH switch (from acidic to neutral). This technology enables us to retain up to ~88% retention of bioactivity of L-glutamine at its point of action.

Further work focuses on steps leading to commercialization of this technology and looks at prevention of aggregation of the micro encapsulates upon storage, their uniform dispersion in the product matrix, improved long term stability when incorporated in the product (beverage) and evaluation of their ease of scalability in a cost-effective manner in line with their incorporation in to a range of beverage products.

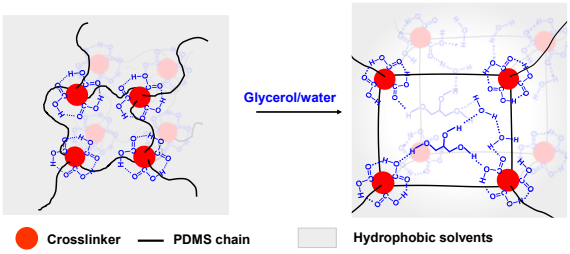
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Cooperative Solid-like Structuring of Glycerol–Water in a Hydrophobic Elastomer: A New Paradigm in Soft Matter Design

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A novel strategy for integrating highly polar glycerol–water mixtures (up to 90 wt%) into a hydrophobic elastomer functionalized with carboxylic acid groups is described [1-3]. The elastomer's molecular architecture and spatial distribution of –COOH moieties are precisely engineered to enable cooperative hydrogen-bonding interactions with glycerol and water, while the hydrophobic silicone backbone provided a soft confinement effect that stabilized these polar domains ((Scheme 1). This design allows systematic organization of glycerol–water mixtures within the elastomer matrix, creating unique hybrid gels with unprecedented structural and mechanical characteristics. Comprehensive characterization using attenuated total reflectance–Fourier transform infrared (ATR-FTIR) spectroscopy, rheology, differential scanning calorimetry (DSC), and confocal Raman microscopy (CRM) reveal that the embedded glycerol–water mixtures predominantly form amorphous, solid-like microdomains. These domains dramatically increase gel stiffness—by several orders of magnitude—mimicking the membrane-hardening response observed in living cells under extreme environmental stress. By simply tuning the glycerol-to-water ratio, we can fabricate tissue-like soft hydrogel materials with predictable and highly tunable mechanical properties. This straightforward approach offers a versatile platform for rational hydrogel design, enabling potential applications in cryopreservation, protein stabilization, tissue engineering, drug delivery, dermatology, and, most notably, artificial cell templates for biomedical research. Our findings highlight the potential of soft confinement and cooperative hydrogen bonding as powerful tools for creating multifunctional biomimetic materials.



Scheme 1 –Schematic representation of the architecture of a rationally designed silicone elastomer.

Keywords: glycerol-water, hydrophobic elastomer, cooperativity, hydrogel and skin protection.

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Polymer Nanocomposites: An Advanced Textile Material

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In recent times, polymer nanocomposites have attracted a great deal of scientific interest due to their unique properties over conventional plastic materials such as superior strength, modulus, thermal stability, thermal and electrical conductivity, gas barrier etc. They are thus finding real and fast growing applications in wide ranging fields such as automotive, aerospace, electronics, packaging, sports etc. In this paper, the focus has been given on developments of polymer nanocomposites as an advanced material for textile applications such as fibers, coatings and nanofibers.

In our research group at IIT Delhi research and development in the area of polymer nanocomposites with a wide range of functionality such as antimicrobial, flame retardant, gas barrier, Weather resistant, EMI shielding, medical applications such as sutures, drug delivery devices, wound dressings etc. for creating a new range of smart and intelligent textiles has been the focus.

The various research studies carried out will be discussed and key findings would be shown. These properties have been induced using a wide range of nanomaterials such as TiO_2, CeO_2 Graphene, Nanoclay, etc. in the matrix like PP, Nylon, TPU etc.

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Accelerating Polymer Design via Machine Learning

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Establishing correlations between the chemistry and sequence of monomers in a macromolecule and its properties is a grand challenge in polymer science. The major bottleneck in understanding polymer's chemisty-property and sequence-property correlations is its astronomically large chemical and sequence space that are intractable via standard experiments and first-principle based computations. Machine learning offers a promising route to overcome this limitation by enabling rapid and data-driven prediction of polymer properties. It can further facilitate the discovery of universal sequence–chemistry–property relationships and guide the rational design of polymers with targeted functionalities. Here, we survey and assess the efficacy of several machine learning methods for predicting polymer properties and propose methods to improve their performance and transferability [1-5]. We further propose new ML pipeline that can tackle both the forward (property prediction) and inverse (sequence/chemistry prediction) problems. We implement these approaches for three representative cases, viz., the single-molecule 3D structure of a copolymer in a dilute solvent condition, copolymer compatibilizer, and glass transition temperature of a polymer, demonstrating the generality of the proposed strategies.

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Synthesis and characterization of functional macromolecular architectures for photocatalytic hydrogen production

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Recent advances in glyco-, fluoro-, and electron-rich monomers and their corresponding polymers have driven significant technological innovation, unlocking a diverse array of practical applications across multiple fields. Synthesis and characterization of 9-vinylcarbazole, quinoline, styrene, pyridine and pentafluorophenoxy-based polymer segmented architectures with acetylated saccharide-based monomers through the iniferter and RAFT polymerizations are reported. The developed polymer architectures, including homopolymers, armed polymers and di- and tri-block copolymers, were characterized using spectroscopic techniques to understand their chemical structure and molecular weight as determined by SEC. Thermal analyses of the polymers were performed using TGA and DSC. To enhance hydrophilicity, the polymer architectures were modified by deacetylation of the pendant acetylated saccharide segments. Subsequently, the deacetylated homopolymers and polymer architectures were utilized to understand the role in photocatalytic H_2 production, employing Pt/HPT, Cd-ZIF-8, CdS and *g*-C_3N_4 as photocatalysts. In the photoreforming process, polystyrene-*b*-poly(methacryloyl-D-glucose) diblock copolymer exhibits a higher hydrogen (H_2) generation rate of 753 µmol/g/h with an AQY (apparent quantum yield) of ~1.84% compared to that of the polystyrene segment alone, 53 µmol/g/h with an AQY of ~0.02%. Further, the fluoro segmented glycopolymer, PPFBM-*b*-PGD (1549 µmol/g/h), has exhibited enhanced H_2 generation compared to the nonfluoro segment containing glycopolymers such as PBM-*b*-PGD (865 µmol/g/h). In addition, hydrophilic, electron-rich pyridine-based glycopolymers, namely, poly(4-vinylpyridine)-*b*-poly(methacryloyl-D-glucose) (P4VP-*b*-PMDG) with CdS nanorods significantly improved photoreforming, achieving an efficient H_2 evolution rate of up to 1685 µ mol/h/g [Figure 1(a)] with an AQY of 4.10%. Moreover, the polymer architecture of cobaloxime catalyst [Co(dmgH_2)(dmgH)Cl_2] onto pyridine-based homopolymer, P4VP-Co, as a photocatalyst, exhibited a H_2 evaluation rate of 4299 µ mol/h/g [Figure 1(b)]. In my presentation, I will discuss the photoreforming mechanism, how macromolecular architecture influences H_2 production, and the resulting byproducts. Specifically, I will cover the interactions between various polymer structures and photocatalysts, the impact of polymer composition on H_2 evolution rates, and the identification and management of byproducts formed during the photoreforming process. Photocatalytic processes with macromolecules offer significant potential as viable technologies. However, challenges remain, including low activity and stability, high costs, and limited visible light absorption. Addressing these issues through targeted engineering approaches is essential to advance the conversion of water or renewable biomass derivatives into renewable energy and hydrogen.

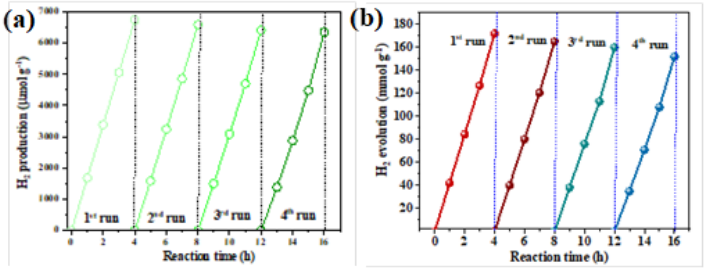


Figure 1. Recyclability studies of (a) CdS photocatalyst over multiple cycles with P4VP-*b*-PMDG as the substrate and (b) P4VP-Co as photocatalyst under visible light irradiation.

Keywords: Polymer architecture synthesis, block copolymer, photoreforming, hydrogen generation

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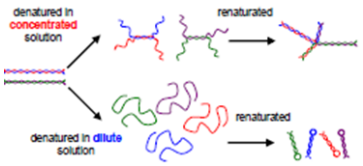
Renaturation Behavior of a Helical Polysaccharide, Xanthan in Various Aqueous Solutions

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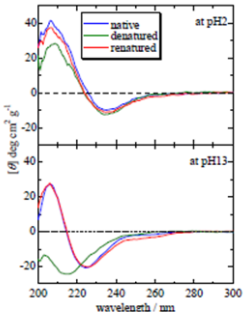
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Xanthan is a polysaccharide used as a viscosity enhancer. Native xanthan forms a double helical structure, but its helices can be unwound by heating in aqueous solutions with low ionic strengths (denaturation), and rewound by cooling in solutions with high ionic strengths (renaturation) as shown in Figure 1.1 Because xanthan is used with other additives in products like foods and cosmetics, and its structural changes induced by the denaturation and renaturation influence the viscosity of the products, it is important to elucidate the denaturation and renaturation behaviors of xanthan in various aqueous solutions. The structures of xanthan renatured in acidic and basic solutions2 were investigated in this study. Figure 2 summarizes the circular dichroism (CD) spectra of native, denatured, and renatured xanthan in aqueous solutions with pH of 2 and 13. Hydrochloric acid or sodium hydroxide was used to control the pH of the solvents. The native solutions were prepared by dissolving xanthan in 0.1 M aqueous solutions of sodium chloride, and measured at 25°C. The denatured solutions were prepared by dissolving xanthan in water without salt, and measured at 80°C. The renatured solutions were prepared by dissolving xanthan in water without salt, heated at 80°C, and measured at 25°C after adding 0.1 M of sodium chloride. The spectra for denatured xanthan were different from those of native xanthan, but the spectra for renatured xanthan were essentially identical to those for native xanthan. These results suggest the unwinding of the helices in denatured xanthan and rewinding in renatured xanthan. While the spectrum for denatured xanthan at pH 13 was drastically different from that of native xanthan, the difference between the spectra of native and denatured xanthan at pH 2 was not significant. These results suggest that the helical structure of xanthan in acidic solutions is more stable at elevated temperatures.

Light scattering, viscosity, and size exclusion online multi angle light scattering measurements were also carried out for the xanthan solutions, and the results will be shown in the presentation.



Figures 1 A schematic model of the renaturation behavior of xanthan in aqueous neutral solution.



Figures 2 Circular dichroism spectra of native, denatured, and renatured xanthan in aqueous solutions with pH of 2 and 13.

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High Performance Oil Spill Adsorbent Materials

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The application of high-performance Adsorbents materials in solving environmental problems has recently sparked a lot of attention due to their unique physical and chemical properties, which make them advanced to traditional adsorbents. The ability to functionalize materials by attaching specified functional groups to their surfaces enables the formation of a variety of designed High Performance Adsorbents materials for the removal of organic and inorganic pollutants. This work contains a thorough investigation and analysis of the application of sophisticated adsorbent materials in the treatment of contaminated wastewaters containing various oils. It will also concentrate on recovery methods and possible solutions for nanomaterial regeneration and reuse.

Keywords: cellulose nanofibril, oil/organic solvent absorption, tunable morphology, reusability.

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Deformation and Damage Behavior of Tough Double-Network Hydrogels

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Soft polymers, such as elastomers or hydrogels, exhibit complex mechanical behavior depending not only on the material structure and properties but also on the external loading, i.e. tension or compression, monotonic or cyclic, multiaxial deformation, etc. To better understand structure-property relationships, systematic investigations using advanced experimental techniques are necessary. Especially for hydrogels, a key challenge is the precise estimation of strains, which may cover several decades (up to more than 1000 %) and deformation fields, that can be extremely inhomogeneous, e.g. due to the necking of a sample [1]. In this contribution, new approaches for strain field analysis specifically designed to address the following challenges will be presented: (i) easily applicable micro-particles for speckle patterns to analyze strain fields at high and in particular inhomogeneous deformation; (ii) sophisticated evaluation software for data analysis of optical and infrared images; (iii) (semi)-transparent materials or deformation-induced color changes of specimens; (iv) *in situ* measurements for comprehensive investigations. The results provide deeper insights into the underlying microstructural mechanisms characterizing the deformation behavior of tough double-network hydrogels, see Fig. 1 [2]. Additionally, the use specific spores for speckle pattern generation on hydrogels proves effective not only in air but also in aqueous environments, e.g. for swelling experiments to identify inhomogeneous swelling due to structural heterogeneities indicating deformation-induced damage. These data help to improve constitutive modeling significantly and pave the way to more accurate predictions of numerical simulations [3].

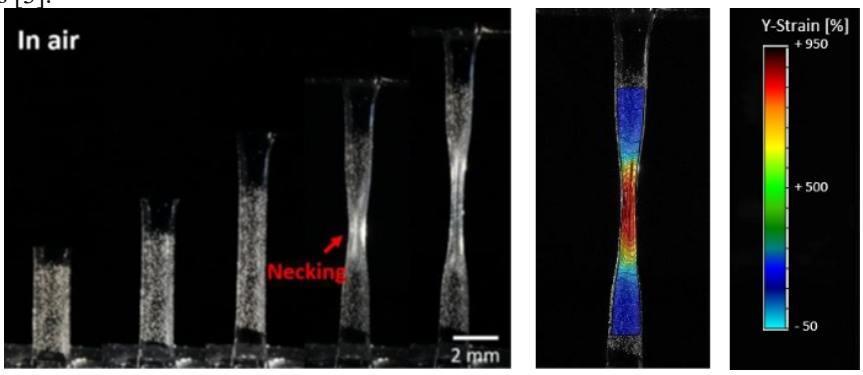


Figure 1: Highly deformed dogbone-shaped specimen of a double-network hydrogel containing a specific speckle pattern (left) for strain field analysis via digital image correlation (DIC, right).

Keywords: Double-Network Hydrogels, strain field analysis, mechanical characterization, damage localization.

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Biodegradable Microgels for Good Health and Zero Hunger: Prospects for Sustainable Future

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Microgels are aqueous, three dimensionally crosslinked polymeric networks. Microgels belong to a special class of colloids that exhibit various attractive features including adjustable size and size distribution, chemical functionality, surface charge, and swelling degree.1 Additionally, ease of post-modification, their large surface area, flexibility and softness, superior colloidal stability and stimuli responsive behaviour (sensitivity to T, pH, ionic strength) enable them as a versatile platform for diverse interdisciplinary applications.1,2 In our laboratory, various synthetic strategies are employed to develop multifunctional polymers and colloidal particles with controlled chemical structure and morphology. The key objective of our research is to design smart biodegradable materials including nano/microgels and to harness their potential for societal benefit keeping sustainable development as a central point.2

In general, the presentation would encompass a few contemporary themes in the domain of biodegradable stimuli responsive nano/microgels for controlled release.2,3,4 In keeping with the latest developments in multidisciplinary research, we have been trying to tap the potential of smart nano/microgels for sustainable agriculture and cancer therapy.2,3 An overview of how multifunctional nano/microgels, built on intuitively chosen molecular/macromolecular building blocks, could be exploited for controlled release under complex conditions as a way to develop smart sustainable carriers of fertilizers or drugs will be presented.4,5 The capability of such nano/microgels to perform multiple tasks, in terms of value addition even after their degradation, will also be discussed.

Keywords: Microgels, Stimuli Responsive, Biodegradable, Controlled Release, Sustainable Development Goals

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25 years of Innovations at BPCL R&D

Saptarshi Ray

As BPCL R&D Centre celebrates its Silver Jubilee, we highlight 25 years of transformative contributions to India's Oil & Gas sector. Established in 2001 on a 65-acre campus in Greater Noida, the Centre has grown into a multidisciplinary hub of 65 scientists supported by highly skilled technical teams.

Our research portfolio spans advanced biofuels, catalysis, green hydrogen, process engineering, modeling and simulation, advanced materials, and circular economy solutions—addressing critical challenges in energy and sustainability. Polymer and petrochemical research remain a core strength, with notable achievements in acrylate and methacrylate value addition, polyolefin development, additive formulations, and membrane technologies.

Accordingly, a major milestone is achieved, namely development of an end-to-end process technology for Hygiene Grade Superabsorbent Polymer (SAP), wherein a high Technology Readiness Level is reached. This includes recipe development in the lab scale, process scale-up studies, and pilot plant commissioning. We are now in the process of designing a commercial plant, which is to be commissioned at our Kochi Refinery. This will make BPCL the first company in India to produce SAP domestically using in-house technology—reducing imports and advancing the vision of Atmanirbhar Bharat.

Collaboration is central to our success. Over the years, we have forged strong partnerships with leading industry and academic institutions, fostering innovation through shared expertise and resources. We are open to new ideas, which are aligned to our current and future businesses.

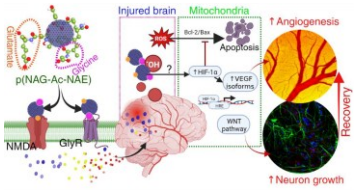
Through relentless innovation and strategic collaboration, BPCL R&D remains committed to strengthening India's energy ecosystem and accelerating the transition to a sustainable future.

Polymeric Nanomedicine for Regeneration and Therapeutic Applications

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In this talk, I will discuss a series of polymeric nanomedicines that were manufactured by our group through the novel synthesis roots, of which many of them have been granted patents for their potential uses in different targeted therapies, regenerative medicines and Biomedical applications from Lab to Hospital Uses. From the list of amino acids, almost 50 various types of polymeric nanocapsules have been prepared. These polymeric nanocapsules are either homopolymers or copolymers. Many of them are solid, porous, and hollow-core-shell in nature. Their properties have been tuned by varying the molecular weight, varying the cross-linking, making them solid monodispersed particles, or hydrogels. Their sizes have been tuned from 50 nm to 250 nm. To validate their suitability, a series of experiments were performed to check the cell viability and toxicity. From this screening, a number of suitable nanocapsules have been selected. Further to find out their selectivity to different target organs, they have been delivered *in vivo* mouse/rat models through IV injection. Based on their efficiency to target organs, systematic treatment procedures have been developed for neuro regeneration and tissue regeneration, drug and gas delivery for cancer and immunotherapy, treatment of inflammation and rheumatoid arthritis (RA), management of infectious diseases without using any conventional drugs. Then these nanomedicines have been used for *in vivo* treatment of various diseases. The uniqueness of these nanomedicines are remarkable such as; they are immunogenic, target specific to organs, can mimic the cellular microenvironment, target to the specific genes responsible for disease such as cancer/tumour or neuronal disorder or responsible for the inflammation and can establish immune memory comprising the long impact of the treatment. Further, these nanopolymeric capsules can also be used for the targeted drug delivery for the treatment of various diseases.



Figures: Representative schematic describes the action mechanism of the polymeric nanomedicine useful for neuro protection.

Keywords: polymer, nanomedicine, tissue regeneration, neuroprotection, anti-inflammation.
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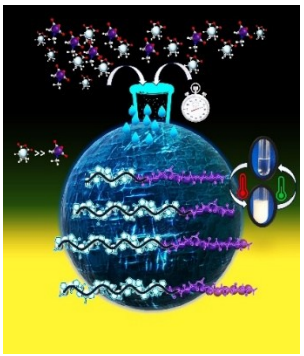
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From Thermoresponsive to Sequence Control: Engineering Polyproline Derivatives

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Among the 20 naturally occurring amino acids, proline is unique in possessing a five-membered pyrrolidine ring in its side chain. This structural feature distinguishes polyproline from other polypeptides: its cyclic side chain prevents backbone amide hydrogen donation. Whereas most polypeptide backbones adopt a trans conformation, polyproline can access both cis and trans states. [1] The arrangement of tertiary amide bonds is critical in determining polyproline's secondary structures. When amides adopt cis geometries, polyproline forms the PPI (right-handed helix), whereas trans geometries yield the PPII (left-handed helix). Multiple factors, including temperature, solvent conditions, and C4 modifications, govern the stabilization of these structures. [1] In addition to this conformational adaptability, polyproline functions as a thermoresponsive polymer, exhibiting pronounced thermal and conformational hysteresis. Importantly, studies reveal that polyproline's thermal transitions are tightly coupled to its secondary structure. [2] In this presentation, I will first describe the rational design of polyproline derivatives to stabilize the PPII helix through functionalization and copolymerization strategies, and how these approaches enable correlation between thermal phase transitions and conformation. [3,4] Finally, I will highlight our recent efforts with proline-NCA monomers in sequence-controlled polymerizations, which open opportunities for preparing synthetic polypeptides with precisely defined primary structures.[5]



Keywords: Polyproline, PPII-helix, Sequence-controlled, Polypeptide engineering.

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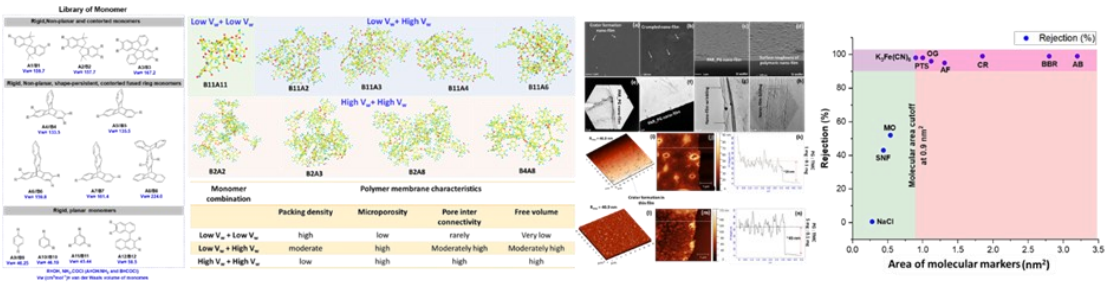
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Monomer geometry-driven Control of microporosity in polymeric thin films for molecular separation

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Polymeric membranes that simultaneously exhibit high mass transport and solute selectivity are highly sought for advanced liquid separation processes.[1,2] Achieving this balance is crucial for scaling up membrane-based separations, where overcoming the permeability-selectivity trade-off remains a persistent challenge. In this work, we demonstrate a monomer geometry-driven strategy to modulate microporosity and molecular selectivity in polymeric thin-film membranes. By incorporating rigid, non-planar, and shape-persistent monomers with high van der Waals volumes, conformational mobility within the polymer chains is restricted, leading to inefficient packing and enhanced free volume. This geometric constraint promotes the formation of interconnected microporosity, facilitating faster mass transport pathways. Furthermore, by carefully tuning crosslinking density and polymerization kinetics, we achieve ultrathin (~10-20 nm) polymeric films that combine high permeability with excellent solute discrimination. The resulting membranes exhibit superior water transport performance compared to state-of-the-art analogues, without compromising selectivity. This study establishes monomer geometry as a key design handle to engineer microporous polymeric thin films for precise molecular separation.[3-5]



Keywords: Monomer geometry, microporosity, polymer thin film, separation.

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Biopolymer-Synthetic Polymer Conjugates for Sustainable Materials

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Biopolymers such as cellulose, collagen, and natural rubber represent a class of sustainable, biodegradable materials that are increasingly utilized for environmentally friendly applications. Their versatility has led to their integration in biomedical devices, textiles, adhesives, and tires. However, the inherent limitations of biopolymers in some cases—such as lack of durability, tunable mechanical properties, or functional responsiveness—often necessitate chemical modification or the incorporation of synthetic counterparts.

In this talk, we will present our recent advances in the functionalization of biopolymers through synthetic polymer integration (Figure 1), with a focus on *click polymerization techniques*. These methodologies have proven effective for the covalent attachment of synthetic polymers such as polyacrylates, polyurethanes, and polytriazoles to biopolymer backbones like bacterial cellulose and natural rubber.[1] The resulting hybrid materials exhibit enhanced mechanical strength, flexibility, and durability. One of the notable outcomes of this work includes the fabrication of leather-like materials and high-performance textiles with potential use in sustainable fashion and protective gear.

The presentation will also focus on our development of superhydrophobic coatings—critical for water-repellent surfaces in a wide range of practical applications. Despite their widespread use, biopolymer-based substrates like textiles and leathers are inherently hydrophilic due to the presence of polar functional groups, which significantly reduce their water repellency. To address this challenge, we have engineered nanocomposite coatings based on polyurethane and functionalized silica nanoparticles. These coatings, when applied to biopolymer substrates, impart exceptional water repellency and durability with breathability, expanding the application scope of natural materials in outdoor and performance-oriented products.[2]



Figure 1. Biopolymers with synthetic polymers for various applications

Keywords: Hybrid material, superhydrophobic coating with breathability, click reactions

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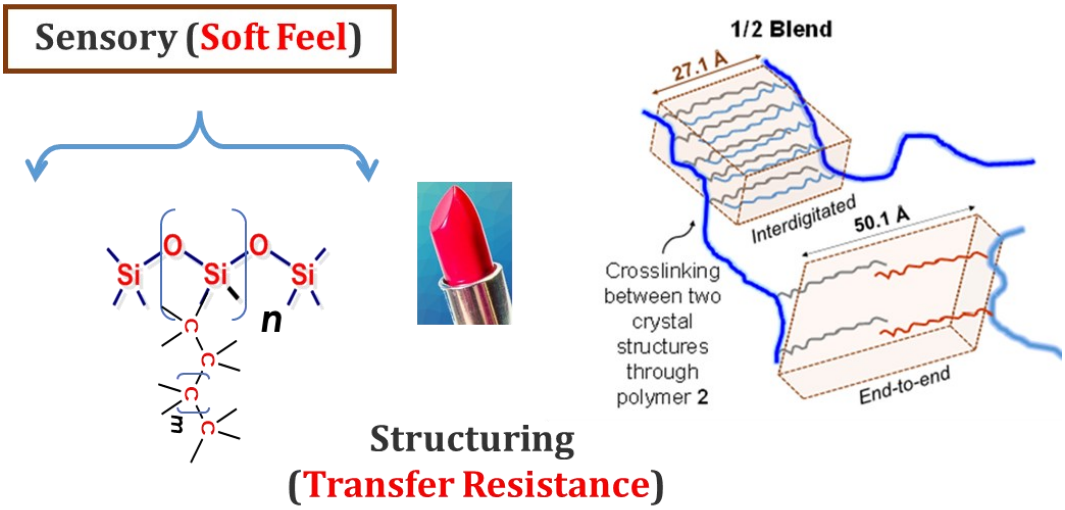
Acknowledgement: We are grateful to the CSIR for funding through Speciality Chemicals Mission Project (MMP 035201).
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Microstructure Driven Self-Sorting of Alkyl Polysiloxanes and their Segmental Dynamics

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Alkyl polysiloxanes are interesting industrial polymers owing to their unique structuring and phase change behavior delivered with enhanced sensory. These engineered polymers find several applications in Color Cosmetics, Skin Care, Coatings and Consumer Electronics. Segmentation of siloxane copolymer with specific alkyl chain length (C18) induces cooperativity in van der Waals interaction among the alkyl chains, resulting in interdigitated as well as end-to-end packing.[1] The research further reveals that, while alkyl chains on random and fully blocked polysiloxanes discriminate against each other, those of partially blocked siloxane copolymers can self-sort with both polymers resulting in amplification of the mechanical strength of the blends. A pre-programmed polysiloxane backbone with methyl alkyl siloxanes separated by dimethyl siloxane segments offers structuring with enhanced compatibility, improved thermal and rheological properties.[2,3]



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Peram Prasad Rao*

The polymer industry is entering a decisive era shaped by sustainability demands, rapid technological change, and global market pressures. While research continues to drive remarkable innovation in materials, processes, and recycling technologies, industrial adoption often lags due to cost, scalability, and policy challenges. This presentation explores how polymer research can be better aligned with real-world industrial and economic realities. It emphasizes the need for collaborative frameworks that integrate sustainability principles with business competitiveness and long-term viability. Drawing from TechnoBiz's international engagement with polymer professionals and enterprises, the session will share insights on industry challenges, evolving market dynamics, and the critical role of education and capacity building in shaping a sustainable polymer future.

Multifunctional Dynamic Covalent Poly(disulfide)s by Amine Activated Ring Opening Polymerization of 1,2 Dithiolane in a Cascade Fashion and Organocatalyzed Pendant Modification

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Dynamic covalent poly(disulfide)s[1] is increasingly recognized as next-generation sustainable and intelligent materials due to their inherent dynamicity, recyclability, and stimuli-responsive behaviour. In this context, the development of a robust and generalizable strategy for synthesizing structurally diverse and functionally versatile poly(disulfide)s is of significant importance. In this work, we report a versatile and efficient cascade ring-opening polymerization (ROP) of 1,2 dithiolane ring[2] in combination with a post polymerization modification strategy to construct a library of functional poly(disulfide)s with broad structural diversity. The polymerization process is initiated by an amine, which activates a dormant thiolactone ring, generating a thiolate anion initiator. This nucleophile then triggers the ringopening of a cyclic disulfide monomer, specifically a 1,2-dithiolane bearing a pentafluoro phenyl ester (PFPester), leading to polymer propagation. Remarkably, the entire polymerization proceeds at room temperature and under open-air conditions, highlighting the operational simplicity and mildness of the methodology[3]. The key innovation of this approach lies in the one-pot, in situ dual chain-end modification, followed by efficient post polymerization functionalization. The presence of PFP-esters along the polymer backbone allows for orthogonal pendant modification with alcohols and amines via organocatalyzed transesterification and amidation, respectively[4]. This sequence of transformations enables multi-functionalization of a single polymer chain, thereby creating highly tunable and application-ready materials. Notably, the mild polymerization and modification conditions preserve the integrity of the disulfide linkages, a critical factor for maintaining the dynamic covalent nature of the material. Unlike previous approaches, which rarely exploited post polymerization routes for structural diversification, this study establishes a new paradigm: a single, end-functionalized poly(disulfide) precursor can serve as a modular scaffold for generating a wide array of pendant ester- and amide-functionalized polymers, all derived through carefully orchestrated monomer design and reaction control. Overall, this work presents a powerful synthetic platform that enables rapid access to structurally and functionally diverse dynamic poly(disulfide)s through minimal synthetic steps. The simplicity, modularity, and efficiency of this strategy make it highly promising for the development of next-generation smart materials with applications in biomedicine, responsive coatings, recyclable systems, and more.

Keywords: Dynamic covalent polymer, poly(disulfide)s, cascade method, ROP, post polymerization

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Designer Particles and Surfaces based on Sustainable polymers and Their Applications in Biomedical

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Designer particles/surfaces, i.e., spheres/flat surfaces with various architectures have gained tremendous attention due to their unique properties and multi-functionalities, making them attractive for emerging applications such as biomedical, energy storage, water remediation, interfacial stabilizers and Pickering interfacial catalysis (PIC). In this particular talk, I will be discussing about the fabrication and application of several types of interesting designer particles/surfaces based on biodegradable polymers for various biomedical applications. For instance, nanocellulose based core shell microparticles will be demonstrated to act as stimuli responsive drug delivery vehicles, where stimulus may range from radiofrequency to magnetic field. In addition, I will also discuss about the unique strategies developed by us for generating micropatterned protein/DNA arrays on biodegradable polymeric surface modified with polymer brushes of suitable functionality. This particular talk will emphasize on the fascinating applications of these types of designer particles/surfaces in various biomedical areas starting from drug delivery to biomedical devices.

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Tannic acid grafted P(NIPAm-co-Acrylated linseed oil) copolymeric stimuli-responsive hydrogels: Tuning of functional properties

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Poly(N-isopropylacrylamide) based smart, multifunctional hydrogels have gained significant attention for biomedical applications, particularly in wound healing, drug delivery, and tissue engineering [1]. A dual-responsive (thermo- and pH-responsive) hydrogel system of PNIPAm with methacrylated tannic acid (ATA) and acrylated epoxidized linseed oil (AELO), has been developed without employing the conventional synthetic cross-linker N,N′-methylenebis(acrylamide) (MBA). The incorporation of bio-derived components (ATA and AELO) makes the hydrogel system more sustainable and biocompatible, with enhanced mechanical and functional properties suitable for advanced biomedical usage. ATA, a plant-derived phenolic compound, serves as a macromolecular cross-linker introducing phenolic hydroxyl groups that impart pH responsive behavior and antioxidant properties [2]. AELO, a derivative of linseed oil, contributes as a reactive plasticizer, improving the hydrogel's mechanical strength and stability through covalent bonding. The unique triblock copolymeric structure of the PNIPAm-ATA-AELO hydrogel ensures flexibility, and a finely tuned lower critical solution temperature (LCST) close to physiological temperature. ATA-induced macro-crosslinking resulted in a porous honeycomb-like microstructure, facilitating nutrient diffusion and enhancing cell proliferation. The pH-responsive swelling behavior was validated across pH 4, 7.4, and 10, with varying swelling ratio owing to phenolic groups in ATA Tensile strength analysis indicated a notable enhancement from 60 kPa to 140 kPa as AELO content increased from 3% to 7%, confirming the reinforcing role of AELO in the polymeric network via covalent interactions. Antioxidant assays demonstrated high radical scavenging activity (84–96%), attributed to the abundant phenolic content introduced by ATA. The hydrogels also exhibit significant antibacterial activity, especially against *Staphylococcus aureus* and *Escherichia coli*, with up to 40% and 35.5% biofilm inhibition, respectively. Mechanistic investigations, including live/dead bacterial assays and ROS generation analysis, confirmed oxidative stress-induced bacterial cell death as a key antimicrobial pathway. Biocompatibility was evaluated through in vitro cell culture studies on neuronal cell lines, which showed enhanced cell proliferation and viability [3]. The PNIPAm-ATA-AELO bio-based hydrogel system presents a versatile, sustainable, and biocompatible alternative to conventional hydrogels by eliminating toxic cross-linkers. The synergistic effect of ATA and AELO confers multifunctional responsiveness, robust mechanical properties, and excellent biological interactions. The tunable thermal and pH-responsive behavior, antioxidant and antibacterial properties, and excellent cytocompatibility make it a strong candidate for medical patches, tissue engineering scaffolds, and other next-generation biomedical devices.

Keywords: Flexible Hydrogel; PNIPAm; Tannic Acid; Linseed Oil; Biomedical Applications

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Tailored Polymeric Architectures *via* Diverse Polymerization Techniques for Biomedical Applications

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The development of functional polymers *via* diverse polymerization strategies is important for various advanced biomedical applications. Techniques like free radical polymerization, condensation polymerization, and RAFT polymerization allow fine control over polymer architecture and functionality, enabling the design of responsive materials tailored for specific biomedical applications. Such precision is crucial in creating materials for antibiotic monitoring, toxin detection, and biofouling prevention. In this study, three novel polymer systems were developed. Firstly, a fluorescent hydrogel, P(OEGMA-co-DIMA), synthesized *via* free radical polymerization using a synthesized anthrapyrazolone-derived monomer, enabled selective detection of tetracycline with an LOD: 1.3 nM, in water and milk, highlighting its potential in pharmaceutical residue monitoring.1 Secondly, Zn(II)-porphyrin functionalized poly(arylene ether nitrile)s, developed *via* condensation polymerization, served as dual-mode colorimetric and fluorometric sensors for cyanide ions relevant to biomedical contexts such as diagnosing cyanide poisoning or monitoring metabolic dysfunction with ultralow detection limits of 0.099 ppb and excellent reusability.2 Despite the detection of biorelevant analytes, polymeric coatings can be used for antifouling applications as well. Charged polyampholytes synthesized by RAFT polymerization were coated onto hydroxyapatite discs to create tunable antifouling surfaces. Among these, polyampholytes with nearly neutral charge showed the least bacterial adhesion from *Streptococcus mutans*, validating their suitability for dental and orthopedic applications. Together, these systems demonstrate how polymer chemistry can be applied through tailored polymerization methods to meet diverse biomedical needs.

Keywords: Biomedical applications, tetracycline, cyanide ion, colorimetric and fluorometric detection, and antifouling coating.

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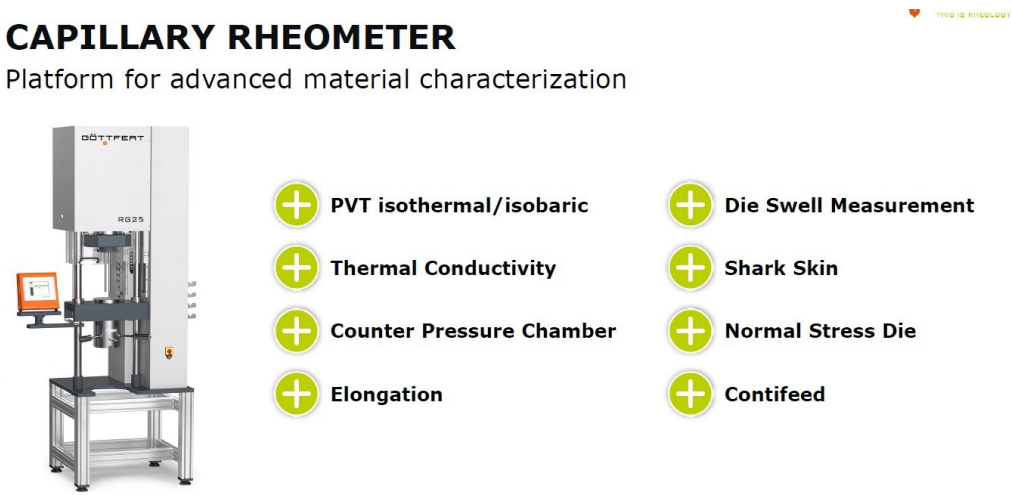
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CAPILLARY RHEOMETERY: A platform for advanced material characterization

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Capillary Rheometry is a versatile platform for the advanced characterization of polymer materials under processing-relevant conditions. It enables precise determination of flow behavior and facilitates the simulation of real industrial processes. By means of modular add-ons, the system provides access to a wide range of complementary material properties. Pressure–volume–temperature (PVT) measurements under isothermal or isobaric conditions allow for a detailed evaluation of compressibility and thermal expansion. Thermal conductivity measurements enhance the understanding of heat transfer within polymer melts. The counter pressure chamber enables the simulation of back-pressure effects, while elongation experiments provide insight into deformation and rupture behavior. Die swell measurements deliver information on extrudate expansion, and the shark skin module allows the investigation of flow instabilities. Furthermore, the normal stress die permits quantification of stress contributions in shear flows, and the contifeed system ensures continuous feeding for reproducible long-term testing. Importantly, PVT data, thermal conductivity data, and viscosity data under varying counter pressures represent essential input parameters for accurate process simulation of polymer materials. As a leading supplier of capillary rheometers, GÖTTFERT Werkstoff-Prüfmaschinen provides a comprehensive and flexible instrumentation platform that supports both fundamental research and industrial applications in polymer science and processing.



Keywords: Rheology, Capillary Rheometry, Viscosity, PVT, Thermal Conductivity

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Glycerol As A Novel Accelerator For Sulphur Vulcanization of Unsaturated Rubbers

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Organic polyols were evaluated as potential accelerators for sulphur, metal oxide, and peroxide vulcanization systems in a range of elastomers, including natural rubber (NR), styrene–butadiene rubber (SBR), butadiene rubber (BR), butyl rubber (IIR), nitrile rubber (NBR), and chloroprene rubber (CR). Among the materials studied, glycerol was identified as the most effective accelerator for sulphur vulcanization of unsaturated rubbers. Rheometric analysis further demonstrated that glycerol provides a reversion-free and scorch-safe cure response. A detailed investigation was carried out using glycerol in a silica-filled SBR/BR passenger car radial (PCR) tire tread compound, and a plausible acceleration mechanism was proposed. In the optimized formulation, 70% of the conventional accelerators—N-cyclohexyl-2-benzothiazole sulfenamide (CBS) and diphenyl guanidine (DPG)—were replaced with 5 phr glycerol. The resulting compound showed substantial performance improvements, including increases of 68% in scorch time, 31.5% in tensile strength, 75.6% in elongation at break, and 9.4% in tear strength. These enhancements are attributed to improved rubber–silica compatibility in the presence of glycerol. Given its effectiveness, low cost, fossil-free origin, and environmentally benign nature (nitrogen- and halogen-free), glycerol represents a promising sustainable accelerator for sulphur vulcanization in tire tread applications.

Keywords: Glycerol; rubber composite; accelerator; sulphur vulcanization
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Rheological Behavior of Mulberry Silk Nanocomposites Solution with Metal Oxide Nanoparticle Integration

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This paper focuses on the integration of metal oxide such as zinc oxide, copper oxide, titanium oxide in silk fibroin formic acid solution (SF) and their influence on rheological properties. The rheological properties of pure SF and silk fibroin/metal oxide nanocomposite solutions are measured by using Modular compact rheometer 302 (MCR), Anton Paar at room temperature. All the tests were carried out by using cone and plate (40-2°) with 0.21mm gap. The amplitude sweep tests were performed at different constant shear rate of 0.1 s-1 and 500 s-1 and variable shear rate ranges from 0.1 s-1 to 1000 s-1. Pure silk fibroin and silk fibroin/metal oxide nanocomposite solutions showed shear thickening behavior at very low shear (0.1 s-1) followed by shear thinning behavior in the tested range of 1-1000 s-1 shear rate and had constant viscosity (Newtonian behavior) at high shear (500 s-1). Viscosities of pure silk fibroin and nanocomposite solutions are mentioned in Table 1. Pure silk fibroin solution has high viscosity at low shear rate as well as at high shear rate in comparison to nanocomposite solutions. Incorporation of metal oxide nanoparticles makes the nanocomposite solution less viscous. However, these metal oxide nanoparticles have different trends in accordance with shear rate. SF/CuO nanocomposite solutions have high storage modulus compared to pure silk fibroin, SF/ZnO & SF/TiO_2 nanocomposite solutions. Addition of ZnO and TiO_2 nanoparticles have reduced storage modulus and loss modulus of silk fibroin solution. Incorporation of CuO nanoparticles tremendously enhanced the storage modulus and loss modulus of silk fibroin solution. Silk fibroin/CuO solution is found to be frequency independent as analyzed in oscillatory sweep measurement. In a creep recovery test, pure silk fibroin solution showed delayed elasticity while nanocomposite solutions showed ideal viscous behavior. Thixotropic or rheopectic behavior of the solution can be examined by rotational shear test with respect to time. It is time dependent viscosity function of the solution. Rotational shear by a series of shear rate 1-100-1 s-1 were used to examine the recovery in structure of silk solution and results are shown in Figure 1. Metal oxide nanoparticles brought better structure recovery in SF nanocomposite solutions.

Sample	Viscosity at low shear (0.1 s^{-1}) (mPa.s)		Viscosity at high shear (500 s^{-1}) (mPa.s)	
	Initial*	Final*	Initial*	Final*
Pure SF	699	5407	261	263
SF/ZnO	284	316	154	151
SF/CuO	154	367	104	105
SF/TiO_2	453	709	144	142

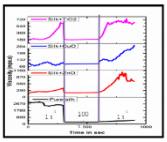


Table1: Comparison of viscosities of Pure silk and nanocomposite solutions at constant low shear (0.1 s-1) and high shear (500 s-1)[1].

Figure 1. Structure recovery in silk fibroin solution by measuring the shear viscosity of pure silk and metal oxide nanocomposite solutions under rotational shear for time dependent behavior in the series of low-high-low shear rate [1]

Keywords: Silk fibroin; Nanocomposite; Metal oxide; Rheology

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Supramolecular Self-Assembled Materials, Thin Films and Their Application in Aqueous Separations

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Supramolecular self-assembled materials driven by non-covalent secondary interactions offer distinct advantages, including ease of synthesis, excellent processability, inherent flexibility, hydrolytic stability, and reversible self-healing. Introducing porosity and hydrolytic stability into these systems requires careful selection of organic linkers to achieve stable and robust open frameworks with high crystallinity, mechanical strength, large surface area, and desired pore characteristics. Our work focuses on addressing challenging aqueous separations that involve processing large solution volumes, particularly for the selective separation of molecular and ionic species. We are developing a series of self-assembled materials tailored for specific functions—such as uranium-selective frameworks for extraction of U from seawater, catalysts for oxygen evolution in saline environments, and sieving systems for precise molecular separations. The key design principles guiding the development of these advanced functional materials include achieving (i) long-range order, (ii) high surface area, (iii) interconnected porosity, (iv) mechanical, hydrolytic, and chemical stability, (v) corrosion resistance, (vi) U selectivity, (vii) redox activity, and (viii) processability, regenerability, and scalability.

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Short-Peptides Based Self-Assembling Systems and Helicity Modulation

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Helical supramolecular architectures are fundamental to the structure and function of biological systems, and mastering their design is key to advancing synthetic biomaterials. While helicity in synthetic molecules has traditionally been controlled through chiral inputs, our research has decisively expanded the boundaries of this paradigm. Our team has pioneered a series of naphthalimide (NMI)-conjugated dipeptides[1-5], which exhibit robust self-assembly in various mixed solvent systems, forming mechanically stable, self-supporting gels. High-resolution morphological analyses unambiguously confirmed the formation of well-defined helical nanofibers. We demonstrated precise control over supramolecular helicity by strategic variation of methylene spacers in the achiral amino acid[5], and deliberate manipulation of the chirality of the α-amino acid component[4]. The inversion of helicity was not only achieved but thoroughly validated using circular dichroism (CD) spectroscopy, DFT simulations, and nanostructure imaging. Beyond molecular structure, we showed that solvent polarity and composition ratios exert a powerful influence over the self-assembly process-enabling solvent-directed helicity switching[2, 3]. This presentation will unveil our latest strategies for engineering supramolecular chirality with precision, and outline how these principles can drive the next generation of adaptive, functional biomaterials.

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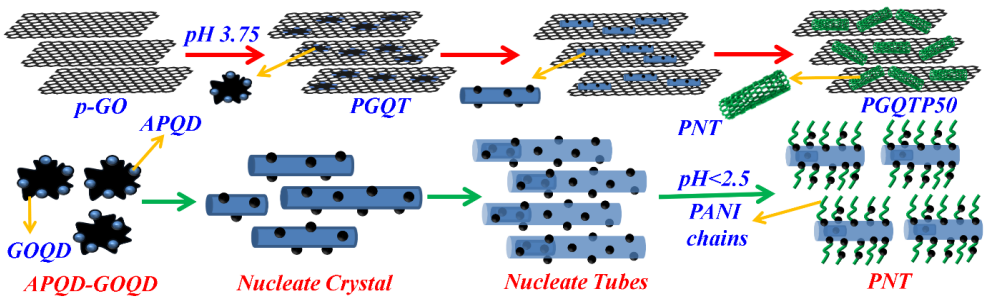
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Preparation of Oligoaniline–Graphene Oxide Quantum Dot Navigated Polyaniline Nano Tubes Intercalated Graphene Sheet with Improved Electrochemical Properties

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Three-dimensional highly conductive polyaniline nanotube(PNT)-intercalated pyrolyzed graphene oxide(p-GO) has been developed as highly electrochemically stable electrode materials. The growth of the PNTs in between the layers of p–GO sheets have been engineered by the trianiline–graphene oxide quantum dot(GOQD). Chemical oxidative polymerization of aniline has been carried out, wherein the polymerization is initiated (seeded) by trianiline owing to its significantly lower redox potential compared to aniline, following an *autocatalytic mechanism*.[1,2] Consequently, a well-directed growth of polyaniline (PANI) chains exhibiting a nanotubular morphology—atypical for aniline polymerization in a weakly acidic medium—has been achieved within the interlayers of p-GO sheets. High electronic/ionic mobility by virtue of the conducting graphene sheets results remarkably high–rate capability of the composite electrode. The composite has shown a remarkably high specific capacitance of ~660 F/g(at 1 A/g) and cyclic stability of ~93.5% after 10000 charge/discharge cycles at two electrode set up.



Scheme 1. Pathway leading to PNT formation in between the p-GO layers.

Keywords: Oligoaniline, Nanotubular PANI, Pyrolyzed Graphene Oxide, Controlled Polymerization, Supercapacitor

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Sustainable Tyre Tread Design Using Nanocellulose Fillers: Selection, Optimization, and Compatibility Enhancement

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The growing demand for de-carbonization is prompting the tyre industry to adopt renewable materials and reduce its environmental footprint. Among emerging strategies, the incorporation of bio-based reinforcing fillers offers a promising pathway to balance high performance with sustainability. This research investigates the potential of nanocellulose as a bio-based sustainable reinforcing filler for tyre tread applications. An initial comparative study was conducted to evaluate different types of nanocellulose i.e. cellulose nanofibres (CNF), cellulose nanocrystals (CNC), and micro-fibrillated cellulose (MFC)—to identify the geometry that provides the most effective reinforcement in a rubber matrix. Following this selection, CNF was partially substituted for carbon black, and the optimal hybrid filler concentration was determined. Subsequent work focused on enhancing the dispersion of nanocellulose within the rubber matrix and improving filler–matrix compatibility. The influence of key mixing parameters (time, temperature, ram pressure, and fill factor) on the properties of carbon-black–CNF hybrid composites was systematically evaluated using the Taguchi Design of Experiments approach. Additionally, the study explored various compatibilizers to strengthen interfacial interactions between nanocellulose and the rubber matrix. Overall, this research demonstrates a viable route to advancing sustainable tyre formulations by integrating bio-based reinforcing fillers while maintaining or improving composite performance.

Keywords: nanocellulose, cellulose nanofibres (CNF), sustainable tyre materials, rubber composites

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From Sand to Space: Enabling Space Missions Through Advanced Silicone Polymer Technologies

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Silicone polymers continue to serve as indispensable materials both in launch vehicles and satellites/spacecrafts, owing to their unique combination of thermal stability, radiation resistance, flexibility at extreme temperatures, and compatibility with diverse substrates. Recent trends show significant advancements in functional surface coatings, adhesive technologies, cure chemistry engineering, and short-fiber reinforced silicone composites, enabling improved performance in demanding Space environments. A major focus of contemporary research is the development of silicone-based, low-absorptivity and high-emissivity coatings for thermal control. These formulations, derived from silicone resins, hybrid polysiloxane architectures, and pigment-engineered systems, enable precise regulation of spacecraft surface temperatures by minimizing solar absorptivity while maximizing infrared emissivity. Their resistance to atomic oxygen, ultraviolet radiation, and thermal cycling makes them preferred materials for the external surfaces of satellites, payload fairings, and deep-Space instruments. Coatings with solar absorptivity as low as 0.04 and infrared emissivity as high as 0.94, while meeting the stringent outgassing requirements for Space applications, have been successfully developed. The demanding requirement of simultaneously achieving low absorptivity and low emissivity to maintain stable internal temperatures has also been fulfilled using silicone-based thermal control coatings. Parallel progress in low-outgassing silicone adhesives and potting materials addresses contamination-sensitive missions, particularly solar cell bonding and bonding of components for satellites and spacecrafts. Modern formulations—optimized through controlled crosslink density, high-purity precursors, and filler surface treatments—demonstrate exceptionally low TML and CVCM values while retaining robust adhesion to metals, composites, ceramics, and polymer substrates. These materials are now available in both room-temperature and elevated-temperature cure chemistries, supporting broader assembly and integration workflows. Furthermore, the refinement of addition-cure and condensation-cure silicone systems has broadened design flexibility. Addition-cure (platinum-catalyzed) silicones offer low shrinkage, rapid and clean curing, excellent thermal stability, and minimal volatile evolution, making them ideal for precision molding, encapsulation, and multifunctional satellite applications. Condensation-cure systems, with their broader substrate compatibility and adjustable pot life, remain valuable for applications where outgassing is not a critical concern. Meanwhile, low-outgassing single-part condensation-cure silicone adhesives are also being developed for Space applications. Innovations in catalyst control, inhibitor technology, and moisture-mediated cure kinetics have enhanced the reproducibility and long-term durability of both chemistries. Another significant trend is the use of short-fiber-reinforced silicone composites, where glass, carbon, or silica fibers are incorporated into silicone resins to improve modulus, tear resistance, creep resistance, and dimensional stability. Polycyclic silicone-based resins play a major role in developing high-temperature-resistant, low-outgassing, and inherently flame-retardant silicone composites. These materials are emerging as promising candidates for high-temperature seals and support components, deployable structures, and low-mass thermo-mechanical interface elements. Tailored fiber orientations and hybrid filler strategies are further enhancing their load-bearing capacity and thermal transport characteristics.
Keywords: silicone polymers, thermal control coatings, outgassing, Space applications.

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ORAL LECTURE

RSC: Building Community

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The Royal Society of Chemistry (RSC) is a learned society with the goal of "advancing the chemical sciences" in our day-to-day life keeping in mind the importance of chemistry in our society. RSC provides a unique platform to connect students, teachers, researchers, scientists together for the development and recognition of professional capabilities and to publish new cutting-edge research. Being an UK organization, with the headquarters located in Cambridge and London, RSC has now extended its global offices to all over the world and since 2010, RSC India office has been actively operating from Bengaluru. With more than 3,000 members and 2nd highest article submissions & articles published across all RSC journals in 2024 from India, RSC is also constantly trying to engage the chemical community here in India with publishing, social, educational outreach, and membership activities in India specific way. My talk would holistically cover all these aspects of the Royal Society of Chemistry.

Bamboo Composites : A Promising Alternative to Wood for Structural Applications

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For any given cross section, the tensile properties of bamboo laminae—which are made from bamboo slivers that are selected from various regions of bamboo culms (Dendrocalamus strictus)—increase from the inner to the outer region and from bottom to top. The analysis reveals that the fiber modulus of bamboo culms increases and fiber strength decreases from bottom to top whereas matrix modulus increases. Scanning electron microscopy was used to examine the fracture behaviour of laminas and LLBCs under tensile loading conditions.

Layered laminate bamboo composite (LLBC), made from laminae and adhesive, increases the usability of bamboo similar to wood. . A comparative cost and mechanical properties analysis of LLBCs with teak wood timber indicates that LLBCs could be used as building and general purposes material like, furniture, beam and column, etc., because there is possibility to increase the volume in any shape and in any direction by increasing number of layers where the thickness and shape of composite can be tailored during fabrication to meet specific requirement. Furthermore use of more bamboo based technology for fabrication of LLBCs could help to improve economy of rural people.

Keywords: Bamboo, Laminate, Wood, Tensile Properties, Fracture Behaviour

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Castor Oil Based Nonisocyanate Polyurethanes and Nanocomposites Via Noncovalent and Covalent Routes; Synthesis, Physicochemical Properties and Anticorrosive and Antifouling Coatings

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In recent time, researchers are intrigued to develop sustainable, chemically modified and commercially available precursors based nonisocyanate polyurethanes (NIPU) for coating applications. Synthesis of NIPU by elimination of toxic isocyanate and NIPU nanocomposites via incorporation of functionalized nanomaterials via covalent and noncovalent route occurred to enhance the performance of NIPU matrix. The primary objective of developing these materials is to venture towards corrosion resistance, antibacterial and antifouling character in coating applications. Synthesis of precursors, cyclic carbonate (CC) was derived from biobased, biorenewable and cost-effective castor oil, which reacted with different diamine as counter reactant to form NIPU. Indeed, amine functionalized silica coated iron oxide nanoparticles (Fe_3O_4@SiO_2-NH_2) was chosen as additive in the formulation of NIPU nanocomposites. In addition to the commercially available long chain aliphatic diamine (1,12-diaminododecane), synthesis of linalool diamine was executed from linalool, a commercially available monoterpene alcohol. Also, amine functionalized multiwalled carbon nanotubes (MWCNT- NH_2) was synthesized to load into the NIPU matrix. Finally, the comprehensive characterization (ATR-FTIR, ^{1}H and ^{13}C NMR, VSM, Raman, MALDI-TOF, HRMS, TEM, XRD, HRSEM with EDS) and characterization of key precursors for their suitability to form NIPU) and respective polymeric nanocomposites. Thermal analysis indicated that both NIPU and NIPU-NC showed good thermal stability with favourable glass transition (T_g) and onset degradation (T_d) temperatures. The hydrophilic properties of above polymeric samples are identified as appropriate for applications in coatings towards antifouling, antibacterial and anticorrosion performance on submerged solid surfaces. As such the results from studies on NIPU and NIPU nanocomposites on coatings on mild carbon steel (MST) indicated the remarkable resistance against E. coli bacteria with reduction of 99.7 and 88.7% respectively. Indeed, the settlements of algae like Spirulina Platensis (S. Platensis) on NIPU and NIPU-F diminished significantly by 71.2 and 52.9% respectively, as effectively compared to that of the control sample. Furthermore, the electrochemical impedance spectroscopy (EIS) studies identified that the corrosion behaviour of both NIPU and NIPU composites attained a comparable level, with impedance magnitude |Z| ~1.6 *10^3 and ~1.7*10^3 (**Ω** cm^2) respectively. Herein, the demonstration of EIS studies in 3.5 wt.% of NaCl and inhibition studies against microorganisms by NIPU and NIPU-F pave new routes to apply for such coatings in protective performance.

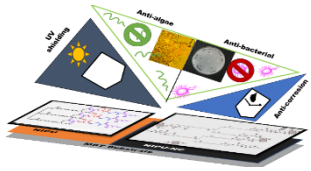


Figure 1: Schematic representation of NIPU and nanocomposites for the coating applications.

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Advancing Polymer Insights Through High-Precision Rheological Characterization

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Rheology plays a critical role in understanding, optimizing, and controlling polymer processing and end-use performance across the entire plastics value chain—ranging from raw material suppliers and compounders to converters and recyclers. This work highlights advanced rheological solutions using TA Instruments' HRx0 and ARES-G2 platforms for comprehensive characterization of polymer melts and solids. These systems integrate multiple capabilities, including rotational and oscillatory rheology, DMA mode, extensional viscosity measurements (EVF), enabling a broad spectrum of polymer investigations within a single platform.

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Effect of TPP on properties of Hot Melt Moisture Cure Breathable Polyurethane Adhesive

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Hot melt moisture cure polyurethane (PUR) adhesives have gained significant attention due to their unique balance of processing convenience and performance versatility. Unlike conventional solvent-based systems, hot melt PUR adhesives are environmentally friendly as they are solvent-free, one-component systems that cure upon exposure to ambient moisture. This curing mechanism enables them to form strong and durable bonds across diverse substrates, making them widely used in industries such as footwear, automotive, textiles, and protective clothing. A recent focus has been on developing breathable adhesive systems to meet the growing demand for laminates in high-performance textiles, where comfort, protection, and durability must coexist. A breathable polyurethane-based moisture cure hot melt adhesive was synthesized using polyethylene glycol as polyol, 4,4'-methylene bis(phenyl isocyanate) (MDI) as diisocyanate, and 1,4-butanediol as chain extender. Triphenyl phosphate (TPP) was added as a plasticizer at varying weight percentages (0, 5, 10, and 15%) to see the effect on the processing parameters and thereafter properties of the cured resin. The resins were characterized for thermal stability and melt viscosity, while polymer films were cast and tested for mechanical strength and breathability. The adhesive was applied in laminating aramid and cotton fabrics, and bond strength was determined using the T-peel test. The synthesized adhesive exhibited a melt viscosity of approximately 4600 **mPa·s at 100 °C**, ensuring good processability for lamination applications. Films prepared from the adhesive demonstrated a **tensile strength of 4.1 N/mm^2 with 220%** of **elongation,** reflecting a balance of strength and flexibility. Incorporation of TPP was found to influence the thermal stability and flow properties of the resin, with higher plasticizer content enhancing flexibility but without much effecting mechanical strength. Whereas, Fabric laminates prepared using the adhesive with optimum TPP enhanced the adhesion strength **to 4.3 N/mm from 2.35 N/mm (without TPP)**. Furthermore, the adhesive films retained desirable breathability, making them suitable for protective textile applications.

Keywords*:* Polyurethane, viscosity, adhesive, breathability, T-peel strength

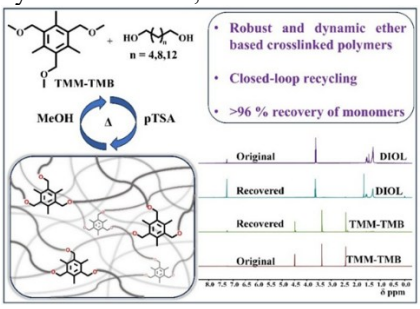
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Design of robust yet recyclable cross-linked polymers via dynamic ether linkages

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Covalently cross-linked polymers are widely utilized for their outstanding mechanical strength and exceptional thermal and chemical stability. However, their permanent cross-links make reprocessing, recycling, and degradation extremely difficult, resulting in inevitable environmental pollution. To address this challenge, dynamic exchangeable bonds have been incorporated into cross-linked polymer networks, resulting in polymers known as covalent adaptable networks (CANs). CANs preserve the robust, thermoset-like properties of traditional cross-linked polymers while enabling reprocessing and recycling. A broad range of dynamic chemistries has been explored to tailor CANs with desired functionalities and performance. However, incorporating dynamic bonds often compromises the thermal stability and mechanical robustness of the polymer, which are essential for many thermoset applications. Designing dynamic linkages that impart both robustness and dynamicity to the resulting CANs is a key challenge. To address this, inspired by the robustness and versatility of ether linkages, we recently introduced benzyl ether based trans-ether exchange as a robust dynamic chemistry for constructing CANs.[1] Subsequently, the closed-loop recyclability and dynamic property tunability in benzylic ether-based crosslinked polymers were demonstrated. Remarkably, the polymers were fully degradable via transetherification, and the monomers were recovered in high yields. The recovered monomers were used to re-synthesize the polymers with pristine-like material properties (Fig.1).[2.] Besides, a strategy was developed for designing the reprocessable and recyclable thiol-ene networks with the incorporation of robust and dynamic ether linkages to regulate creep and dynamicity in the networks.[3] Most recently, another robust and dynamic chemistry, benzyl thioether, was introduced to design the CANs.[4] In my talk, I will present the design strategy, thermal and mechanical robustness, dynamic behavior, and both mechanical and chemical recycling of these cross-linked polymers.



Keywords: Dynamic ether, Recyclable thermoset, Robust polymer, Closed loop recycling, Dynamic thioether

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Preparation and application of indigenous polymeric hollow fiber membrane

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Polymeric hollow fiber membranes have gained significant attention over the past few decades as a versatile platform for separation and purification technologies. Their unique features, such as a self-supporting configuration, excellent flexibility, high packing density and a large surface area-to-volume ratio make them particularly suitable for efficient and compact separation systems. The hollow fiber geometry further enhances mass-transfer efficiency, enabling their adoption in a wide spectrum of applications. These include medical uses (blood fractionation and hemodialysis), water reclamation and desalination, ultrafiltration, microfiltration, nanofiltration, reverse osmosis, gas separation, and removal of volatile organic compounds (VOCs) from aqueous streams. In this context, the development of indigenous polymeric hollow fiber membranes is of strategic importance, offering cost-effectiveness and self-reliance in critical technologies. Their successful utilization has been demonstrated in juice clarification, drinking water purification, biomolecule separation, industrial effluent treatment, and the remediation of toxic pollutants. This presentation highlights the preparation strategies, performance characteristics, and wide application potential of these polymeric membranes in addressing environmental, industrial and healthcare challenges.



Figure 1: (a) Spinning of hollow fiber membrane, (b) hollow fiber membrane based filter and (c) cross sectional SEM images of hollow fiber membrane

Keywords: Hollow fiber membrane; ultrafiltration; nanofiltration; microfiltration, water treatment.

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Fine Tuning of Mechanical Properties and Enhancement of Biodegradation Potential of EPDM/Pistachio Shell Biocomposite with the Help of an Octene Polyolefin Elastomer

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Ethylene propylene diene terpolymer (EPDM) is formed by a combination of ethylene, propylene and unsaturated diene monomers. High mechanical property and excellent resistance to heat, ozone, UV and oxygen [1] make them superior in many applications such as roofing membranes, gaskets, electrical wires and cables. EPDM, being a non-biodegradable polymer is becoming an environmental issue after post-use discard. To incorporate biodegradable component into it, EPDM/pistachio shell powder (PSP) biocomposites are prepared. Composite formation is successful but up to a certain composition (40 wt% filler), beyond which processability is hampered and composite preparation is not possible. Further, EPDM has been blended with polyolefin elastomer (POE) followed by composite preparation. EPDM/POE blend (80 wt%/20 wt%) (EP82) is seen to be able to hold up to 60 wt% PSP rendering useful properties such as elongation at break to be around 120 % for 60 wt% PSP loaded composites (Figure 1). First, 40 wt % PSP is reinforced in pure EPDM and POE polymers and prepared composite is denoted and EP40 and PP40, respectively. Prepared composites with 40 wt%, 50 wt % and 60 wt% PSP reinforced EP82 are denoted as EPP40, EPP50 and EPP60, respectively. The filler-containing capability of EPDM is increased from 40 wt% to 60 wt% due to enhancement of processability of the composite after addition of POE. Mechanical properties investigation shows that Young's modulus and hardness of the biocomposite increases with PSP filler content [2]. In DMA studies, three parameters such as storage modulus (G') (Figure 2), loss modulus (G") and loss factor (tan δ) are investigated to measure storage and lose of energy under mechanical stress at different temperatures. For 60 wt% PSP reinforcement in EPDM/POE blend, the storage modulus and loss modulus are increased by around 1000 % and 1500 % with respect to those of EPDM/POE blend at 30 ˚C temperature, respectively (Figure 2). Thermal studies (thermogravimetric analysis) did not reveal any notable demotion of thermal stabilities of EPDM, POE and PSP in the prepared composites. Surface morphology study reveals homogeneous dispersion of PSP particles in the polymer blend matrix.

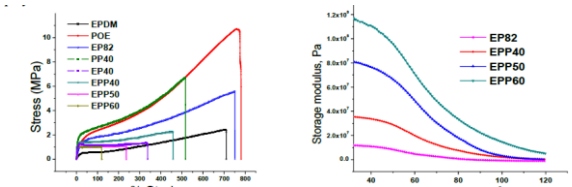


Figure 1 - Stress-strain curve

Keywords: EPDM, pistachio shell powder (PSP), Young's modulus, storage modulus.

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Smart Materials for Energy Storage and Energy Saving Applications

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Smart materials are a class of materials that can respond to external stimuli from their environment and react to them in a predetermined mode. Among the stimuli-responsive materials, chromic materials switch their color and have garnered significant interest and found diverse applications in various fields. Electrochromic (EC) materials modify their chromaticity on applying electric stimuli and have several advantages over other chromic materials.[1] Considering the importance of electrochromes and the significance of such materials in various disciplines of day-to-day life, we intended to develop a new class of electrochromes to construct smart windows, rear-view mirrors and smart displays. The main aim was to create novel EC materials with electrolyte polymer gels.[2] We have chosen tetrabenzofluorene as the core molecule and functionalized them with different functional groups to evaluate the impact of those substituents on electrochemical and EC properties. In one approach, thiophene derivatives, such as regioisomers and thiophene-based acceptor units, are substituted into the core since thiophene derivatives reportedly exhibit remarkable EC properties.[2] In another approach, we deliberated creating an acceptor-donor-acceptor system by functionalizing the core with highly electronegative moieties such as nitrile and fluoro-aldehyde because such ADA systems generally show unique properties (Figure 1).[3] The real-time applicability of the synthesized electrochromes is evaluated by fabricating devices in three states: solution, solid, and gel state, and the devices displayed excellent performance.[4] In addition, the devices in the solid and gel state can store imported energy, and the stored energy can be reused to charge electronic gadgets.[5]

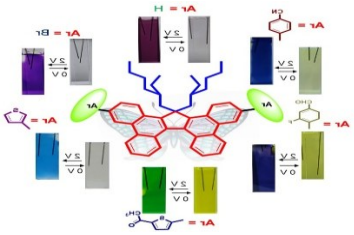


Figure 1 :Tetrabenzofluorene molecules exhibiting electrochromism

Keywords*:* Tetrabenzofluorene, electrochromism, electrofluorochromism, smart materials, energy-saving smart windows.

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Nano/micro scale mechanical characterization for polymeric materials and their correlations to macro scale measurements: A way to reduce time-to-market (TTM)

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Product developers frequently must iterate between formulation development at the gram-scale and validation studies at the kilogram-scale for new materials in order to reach a desired optimal state prior to large-scale production, which increases their development cycle time and hence the time to market (TTM). Small scale mechanical characterization often requires less material and shorter execution time, yet it can be difficult to convince polymer community about the relevance of the results in comparison to bulk mechanical testing (Tensile, Impact, Creep, Viscoelastic etc.). This paper will discuss the feasibility and limitations of using small-scale mechanical testing as an alternative/complementary to bulk-scale testing of thermoplastic polymers by performing mechanical testing at both nano/micro and macro length scales. All the work presented herein was performed at room temperature on three injection molded control samples: one amorphous polycarbonate (Am_PC, Tg=146ºC, Tm=280-310ºC), and two semicrystalline polymers namely polypropylene and polyethylene (SC_PP, Tg=11ºC, Tm=160ºC) and SC_PE, Tg= -117ºC Tm=134ºC). We found that under certain experimental conditions during nanoindentation (NI) (i.e. fast loading and slow unloading), material creep begins to impact the unloading portion of the test which directly influences the resulting elastic modulus and hardness measurement by Oliver-Pharr method [1]. Cyclic nanoindentation also revealed that the anelastic deformation after several cyclic loading-unloading events (30 cycles) is the highest for polyethylene-based polymer, followed by PP based and PC based polymers.

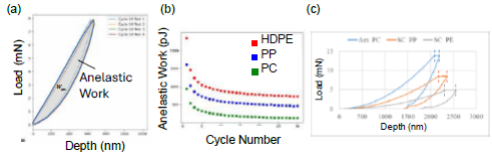


Figure 1a- Anelastic work vs Cycle Number from NI, 1b- area under the curve at different cycles for all three polymers, and 1c- comparison of typical load-unload curves using CSM technique.

Hold segment marked between dotted line (Fig. 1c) indicated higher creep for PE based material compared to PC based material and that is the indication of higher visco-elastic and viscoelastic effect on the measurement. Continuous stiffness measurement (CSM) techniques were performed on the surface and at the cross-section to find the properties on the surface and at the core of the injection molded part. NI modulus is higher compared to Tensile modulus and this is usually attributed to the effects of creep, viscoelastic property and the difference in strain rate on the NI measurement and ISO standard tensile test (Table 1). One third of Hardness measured at the core matches well with tensile yield strength (YS). Detailed discussion will be presented on ways to correlate small scale and bulk measurement, their challenges, and future directions with the end goal being to implement fast and reliable techniques to reduce product development cycle time to reduce TTM.

Keywords: *Nanoindentation, tensile testing, modulus, hardness, yield strength*

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Performance of ABPBI and Aramids as Outer Layer in Fire Protective Clothing Application: A Comparative Study

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2. Gharda Chemicals Ltd, Mumbai, India

High-performance inherently flame-retardant fibers, like aramids, polybenzimidazoles, polyamide-imides and polyimides are finding application as outer shell of firefighter protective clothing. Amongst these, Poly[2,2'-(m-phenylene)-5,5'-bisbenzimidazole], commonly referred to as Polybenzimidazole (PBI) stands out for its nonflammability, low smoke emission and minimal toxic off gases. In the same category, Poly (2,5-benzimidazole) (ABPBI) can be prepared using less carcinogenic monomer and offers higher thermal and flame resistance with an exceptionally high Limiting Oxygen Index (LOI) of ~72, which is much higher than PBI (~38.3) and aramids (~25). Despite its potential, ABPBI's fire retardancy studies are limited. The present study aims to ABPBI fabric's fire protective capabilities for potential integration into firefighter clothing as the outer layer and compare with the conventional aramid based fabric. For this purpose, twill woven ABPBI and aramid fabric (2/1, 260gsm) was prepared, characterised and subjected to vertical flammability tests and exposure to radiant as well as convective environments. Both the fabrics did not exhibit any after-flame or after-glow phenomenon and exhibited a char content of <5%. Interestingly, the ABPBI fabric retained its flexibility, dimensional stability as well as strength without undergoing any embrittlement, which was further confirmed by morphological studies. Dynamic Mechanical Analysis revealed a 10 fold decrease in the storage modulus upon flame exposure (30s duration, 84kW/m^2). This was associated with a 26.2 % reduction in oxygen content, with a concomitant increase in carbon content (9.3%) as confirmed by EDS analysis. Radiant exposure (10kW/m^2) led to insignificant decrease in the mechanical properties of the fabric. The ensemble with ABPBI based outer shell exhibited a thermal protective performance of 60 cal/cm^{2}s, exceeding the mandatory requirement of 35 cal/cm^{2}s. Under similar exposure, however, the aramid fabric exhibited a break open phenomenon due to the relatively brittle nature of the degraded sample. Our studies clearly highlight the improvements offered by ABPBI fibers in the field of fire protective clothing, particularly as the outer shell material.

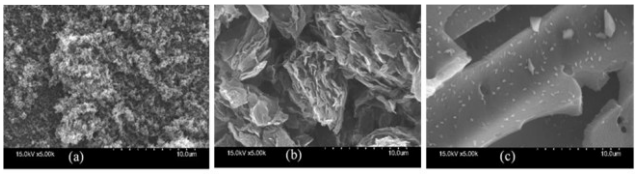
Keywords: ABPBI, Aramids, Firefighter Protective Clothing

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Sustainable LDPE Composites Reinforced with Carbonized Coconut-Coir: A Comparative Study with RGO and Carbon Black

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Low-Density Polyethylene (LDPE) composites were fabricated by incorporating three carbon-based fillers: Carbon Black (CB), Reduced Graphene Oxide (RGO), and Carbonized Coconut-Coir (CC); each at a fixed loading of 1 wt%. Carbon black is a conventional petroleum-derived filler known for its excellent ultraviolet (UV) stability in outdoor applications. In contrast, RGO and CC represent advanced and bio-derived low cost alternatives. This study aims to compare the morphological, structural, thermal, mechanical, and electrical properties of these composites to identify promising filler systems for high-performance insulating materials. FTIR analysis of the fillers revealed the presence of various oxygen-containing functional groups, particularly in RGO and CC, suggesting their potential for enhanced chemical interaction with the LDPE matrix. Scanning Electron Microscopy (SEM) further confirmed the distinct morphologies of the fillers: CB exhibited densely packed, irregular aggregates; RGO displayed thin, crumpled sheet-like structures; and CC showed elongated, fibrous morphology with a relatively smooth surface. All composites were formulated with 1 wt% Maleic Anhydride grafted LDPE (MA-g-LDPE) as a compatibilizer to improve filler–matrix interfacial adhesion. Differential Scanning Calorimetry (DSC) demonstrated improved crystallization behavior and thermal stability in RGO- and CC-filled composites, suggesting better thermal performance under elevated temperature conditions. Mechanical characterization indicated that RGO-filled composites exhibited the highest tensile strength and elongation at break (%EB), followed closely by CC, owing to better interfacial bonding facilitated by MA-g-LDPE. CB-filled composites showed lower mechanical performance. Electrical measurements showed that the CC composite achieved excellent volume resistivity (VR), making it suitable for high-resistance insulation, while both RGO and CC composites exhibited superior dielectric strength (DS) compared to CB. Accelerated UV ageing for 14 days revealed that the CC-LDPE composite retained electrical and mechanical properties comparable to CB-filled composites, confirming its outdoor durability. In conclusion, carbonized coconut-coir offers a sustainable, high-performance alternative to petroleum-based fillers, enabling the development of eco-friendly, multifunctional LDPE insulating materials.



Figures 1 – SEM Images Depicting the Morphology of (a) Carbon Black, (b) Reduced Graphene Oxide, and (c) Carbonized Coconut-Coir

Keywords*:* Carbonized Coconut-Coir, FTIR analysis, Morphology, electrical properties, UV ageing

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Sustainable 3D-Printed PLA Scaffolds Reinforced with Coconut Shell Derived Nanocellulose for Tissue Regeneration Applications

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Tissue regeneration is a critical biological process involving the repair or replacement of damaged tissues and organs. While traditional materials such as ceramics and metals have been widely used in scaffold design, polymers have gained increasing attention due to advantages like low density, cost-effectiveness, corrosion resistance, and high strength-to-weight ratio. Among fabrication methods, 3D printing - particularly Fused Deposition Modeling (FDM) - has emerged as a promising approach for producing scaffolds with customizable architectures and high dimensional precision at relatively low cost.

This study explores the fabrication of nanocellulose-reinforced poly lactic acid (PLA) scaffolds using 3D printing technology. Nanocellulose was extracted from coconut shell powder (CSP) through a two-step chemical process involving delignification and mercerization, using sodium hydroxide, sodium chlorite, and glacial acetic acid. The extracted nanocellulose (NC) was then incorporated at 1 wt% into PLA to form bio-composite scaffolds.

Both pure PLA and PLA-NC scaffolds were 3D printed using FDM and evaluated comparatively. Characterization techniques were employed to investigate morphology, structure, crystallinity, biodegradability, and biocompatibility. Scanning Electron Microscopy (SEM) revealed the presence of interconnected pores, while X-ray Diffraction (XRD) confirmed enhanced crystallinity in nanocellulose-reinforced scaffolds. Biodegradation behavior assessed in phosphate-buffered saline (PBS) showed a weight increase over 50 days, indicating hydration and degradation onset. Furthermore, MTS assay performed after 24 hours demonstrated good cell viability, highlighting the biocompatibility of the developed scaffolds.

These results suggest that coconut shell-derived nanocellulose is a promising reinforcement for sustainable, biocompatible scaffold development in tissue engineering applications.

Keywords: scaffold; tissue regeneration; polylactic acid; PLA; coconut shell powder; nano-cellulose; FDM; 3D printing; compounded filament; nanocomposite; biocompatibility; biodegradation.

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Advantages and Challenges Associated to the Industrial Use of Nanomaterials in Polymer Nanocomposites

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Nanomaterials, in the present era, have emerged as transformative additives for Polymer Nanocomposites. Their large surface area, superior mechanical, thermal, and barrier properties have enabled them as highly reinforcing fillers for polymers [1]. Popular carbon-based nanomaterials, such as graphene, have exhibited revolutionary reinforcing abilities in rubbers and plastics in numerous studies conducted in the last decade [2]. However, several challenges hinder their large-scale industrial utilization. Difficulties in achieving uniform dispersion of graphene in polymer, especially, rubber matrix is still the greatest challenge. Weak interfacial bonding between graphene and rubber matrix often leads to phase separation. High production cost, poor reproducibility and scalability are the other major issues that obstruct its industrial use [3]. Additionally, variation in the synthesis and functionalization techniques lead to inconsistent quality and performance of nanomaterials like graphene. However, it has been possible to overcome some of these challenges by careful selection of dosage, proper functionalization and by controlling the processes involved [4]. Even conventional techniques, such as internal mixer or two roll mills mixing can be carefully used to incorporate small amounts of graphene along with conventional fillers to achieve significant properties in rubber-graphene nanocomposites [5]. Several studies conducted by IRMRI have displayed significant improvement in properties of graphene-rubber nanocomposites. Mechanical and dynamic mechanical properties, abrasion resistance, and ageing properties of these nanocomposites have shown promising results. Hence, it is possible to exploit the full potential of nanomaterials, such as graphene, by the modern polymer and rubber industries by focused and systematic application-oriented investigations and optimization of process parameters.

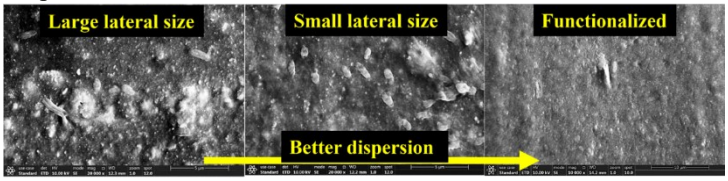


Figure 1: Dispersion of graphene in rubber matrix

Keywords: Nanomaterials, Graphene, Graphene-Rubber Nanocomposites

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Rheological Insights into the Effect of Particle Shape on the Flow Separation Marks in Particulate Composite Solid Polymer Grain

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Composite solid polymeric grain (CSPG) used in missiles and launch vehicles comprises of an amorphous Hydroxyl terminated polybutadiene (HTPB)-Toluene di-isocyanate(TDI) cured resin matrix embedded with highly loaded (86-90%) oxidizer & metallic fuel particles. Often, while processing star-shaped CSPGs, they develop flow separation marks(FSM) upon completion of curing. Present investigation considers cured CSPG grains that are identified and classified based on their head end (HE, side connected to igniter), nozzle end (NE, side connected to nozzle), lobe (L-sharp region), and valley(V). As most severe marks are observed near transition region of NE-V/L compared to their HE side, samples are prepared from both HE and NE-V/L sides of the CSPG with & without FSM and subjected to frequency/strain rate (0.1/9.6E-03 to 50/0.493 Hz/s^{-1}) ramping and 10 hr. relaxation experiments at 27°C using dynamic mechanical analyzer (DMA) to estimate time dependent modulus. Further, DMA experiments are carried to capture the 20-hour transient viscosity behavior of CSPG slurry. Preliminary experimental data reveal that the samples collected from CSPG with FSM have 20 kgf cm^{-2} difference in infinitely($t\rightarrow\infty$, strain rate$\rightarrow$0) cured modulus(ICM) among NE-V and NE-L. However, samples from the NE-V/L side of the CSPG without FSM exhibit only 5-6 kgf cm^{-2} difference in ICM. The difference in ICM of samples prepared from HE sides of both CSPGs (with and without FSM) are found to be within a narrow band of 1-4 kgf cm^{-2}. Considering these alarming differences in ICMs, the modulus time response captured at lower time (high strain rate) regime is merged with infinite time regime (relaxation time) data for understanding the complete modulus time profile. Further, the obtained modulus vs. time response has been converted to viscosity vs. time response based on Eyring's viscosity theory [1-2] to make a conjunction with the viscosity data modelled through the rheological model [3]. A differential multiplication factor (ICM_{Lobe}/ICM_{Velley}) is applied to lobe viscosity data to compute the viscosity of the slurry in the valley. The difference in infinitely cured viscosity (ICV) among NE-L and NE-V is found to be in the range 1,35,832 Pa-s for CSPG with FSM, against the difference of 45,056 Pa-s for CSPG without FSM. Further, for a better understanding of the phenomena, a constitutive model has been constructed to represent the viscosity of both regimes (V & L) as a function of time, particle shape, and volume fraction. Based on the solutions of the models for both the regime for CSPG with FSM, it is confirmed that there would have been a significant solid volumetric packing fraction (VPF) difference of ~6% between NE L& V in comparison to the 0.4% difference in VPF for CSPG without FSM due to large dispersion in the particle aspect ratio in the NE-V& L region. Finally, clear fundamental insights can be built up on the phenomena of the effect of filler particle aspect ratio [4] difference between the layers on flow restriction due to slurry particle movement, resulting in FSM upon completion of curing.

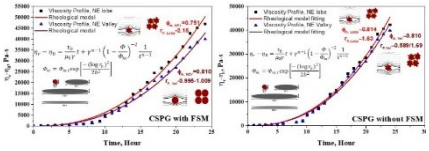


Fig: Viscosity vs. time as a function of packing fraction(Φ), aspect ratio(r_P)for CSPG with and without FSM

Keywords: Eyring, Viscosity, Rheology, Curing, flow

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Enhancing Fire Performance of Polyurea Coating Using a Chemically Reactive Flame-Retardant Strategy

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The growing demand for advanced damage control materials capable of withstanding high strain rate impacts has prompted increased interest in polyureas. These materials are particularly attractive for retrofitting existing platforms due to their spray-on application, rapid cure times, and low volatile organic compound (VOC) emissions. However, the protection performance of polyurea (PU) coating is limited due to its intrinsic flammability. In order to develop a polyurea coating with outstanding flame retardant and mechanical properties simultaneously, in this work amine terminated phosphorylated compounds were introduced into polyurea matrix. These terminated phosphorylated compounds were prepared by the condensation reaction of phenylphosphonic dichloride with diamines of different molecular weights, which subsequently reacted with the isocyanate to form urea linkages during the reactive spraying process. The inclusion of phosphorus containing amines is expected to lead to introduction of flame retardancy in the resultant polyurea coating. Thermal stability and combustion behavior of polyurea composite coatings were studied by thermogravimetric analyzer and cone calorimeter. Results showed that PU composite sample with 10 wt% amine terminated phosphorylated compounds into exhibited remarkable flame-retardant and fire protective performance. The improved fire retardance was evidenced in terms of increased char content, lower heat release rate as well as lower total heat release rate in flame retardant compositions. The total heat release rate (THRR) was decreased by 47.8 % on incorporation of only10 wt% amine terminated phosphorylated compounds

Keywords: Polyurea, Phosphorylated amine, THRR

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Microwave-Assisted Depolymerization of Polymethacrylates

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Advancing sustainability in the polymer industry requires efficient, ecofriendly recycling strategies. This study introduces a catalyst-free, microwave-assisted depolymerization method for RAFT-terminated polymethacrylates, utilizing methanol as a dual-functional cosolvent to enhance microwave absorption and provide a benign reaction medium. (**Fig. 1**) The effectiveness of this approach was demonstrated primarily with poly(methyl methacrylate) (PMMA), including variations in molecular weight (Mn ≈ 5k, 12k, 17k g/mol) and RAFT end-groups (dithiobenzoate and trithiocarbonate). Applicability was further confirmed with poly(2-hydroxyethyl methacrylate) (PHEMA) and poly(benzyl methacrylate) (PBzMA). Depolymerization efficiency showed strong temperature dependence, with significant monomer recovery observed between 110 and 140 °C, while operating effectively at high repeat unit concentrations (up to 200 mM). (**Fig. 2**) This rapid, catalyst-free process, operating efficiently at elevated temperatures like 120 °C, presents a green, scalable, and economically viable recycling solution, aligning with circular economy principles to mitigate polymer waste.

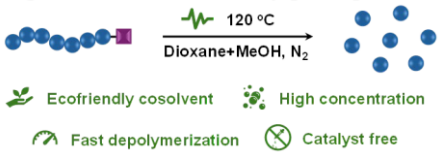


Figure 1. General scheme for microwave-assisted depolymerization.

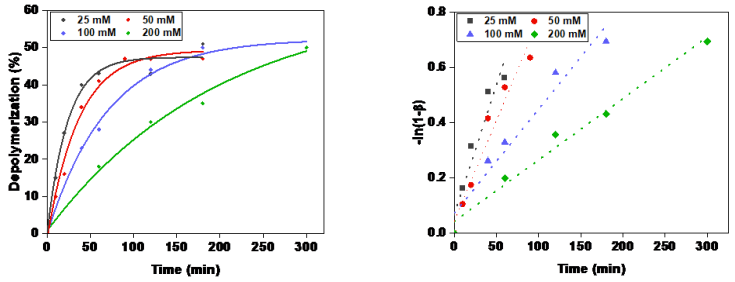


Figure 2. Depolymerization kinetics and characterization. (A) Monomer recovery versus time for PMMA12K-DTB at varying concentrations ([RU]0 = 25, 50, 100, and 200 mM). (B) Plot of −ln(1 – β) vs time, where β corresponds to monomer recovery for depolymerization of PMMA12K-DTB at different concentrations.

Keywords: Depolymerization, Chemical recycling, Microwave, RAFT polymerization, Sustainability

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Development of Ergonomically-designed Indigenous Structural Fire Protective Boots

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Structural Fire[1] Protective Boots form an indispensable component of Personal Protective Equipment (PPE) meant for Structural firefighters. Presently, a major fraction of Indian firefighter fraternity isn't using designated Structural Fire Protective Boots, and the minor fraction which is using designated fire boots, have them imported. The imported boots, apart from being extremely cost-intensive, are not designed for Indian built and, therefore, result in grievous injuries to the wearer. Therefore, there existed a dire necessity for indigenous development of this product that conformed with the applicable Performance Standard, and that was ergonomically-designed[2] for our Indian firefighters for maximal safety and performance efficiency of these front-line warriors during a firefighting operation. However, before embarking upon the project of indigenisation of the product, it was mandatory to understand the perception of our Users about this product. For this purpose, a Questionnaire was formulated and shared with the Defence Fire Services as well as with Indian State Fire Services. Both "Online" as well as "Offline" mode were resorted to for a wider reach among the Users. The aim was to subjectively evaluate the boots currently being used by the firefighters in these units, on several aspects that cumulatively govern the safety and performance efficiency of a firefighter while wearing these Boots and out on a firefighting operation. The concerns (due to the boots being either not meant for firefighting operations, or else not suited to Indian anthropometry and Indian firefighting conditions) and suggestions-for-improvement with regards to these currently used boots were vividly brought out by the responders through their feedback. Utilizing these inputs, an ergonomically-designed Structural Fire Protective Boot was developed using indigenously-developed raw materials. The developed Structural Fire Protective Boot conforms to the Indian Standard, IS 18582-Part 6, formulated for certification of this specialized product.

Keywords: Structural fire, ergonomic design, indigenous development, Indian firefighting conditions

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Redox-Activable Heavy Atom-Free Photodynamic Therapy

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Photodynamic therapy (PDT) is a minimally invasive and spatially controlled cancer treatment strategy that relies on light-activated photosensitizers (PS) to generate reactive oxygen species (ROS), leading to localized cell death. However, conventional PSs often contain heavy atoms or metal centers, which increase ROS production efficiency but are associated with significant dark toxicity and poor biocompatibility. To overcome these limitations, heavy atom-free organic PSs have emerged as safer alternatives1. We report the design of a redox-activable PDT system based on a newly synthesized heavy atom-free thionated naphthalene-monoimide (NMI-S), which demonstrates excellent ROS generation upon photoirradiation2.For selective intracellular delivery and activation, NMI-S was non-covalently encapsulated in redox-responsive polymersomes prepared from an ABA-type amphiphilic block copolymer containing a disulfide-rich hydrophobic core. Interestingly, ROS generation was suppressed in the aggregated state within the polymersome, likely due to exciton coupling and reduced intersystem crossing, as supported by UV/Vis spectroscopy and TDDFT calculations. Upon exposure to glutathione (GSH), which is elevated in cancer cells, the polymer disassembled, releasing NMI-S in its active monomeric form, thereby restoring ROS generation and photocytotoxicity. Additionally, we developed a covalent polymer–PS conjugate system using a PDS-derived block copolymer (P1)3. The PS was attached via a carbonate linker, which underwent a GSH-triggered disulfide cleavage and cascade thiol-mediated release reaction4. The resulting nanoparticles showed efficient cellular uptake and light-induced cancer cell killing (>95%), while remaining non-toxic in the dark or in GSH-deficient cells. This dual-triggered, heavy atom-free platform highlights a promising direction in activable PDT for precision cancer therapy.

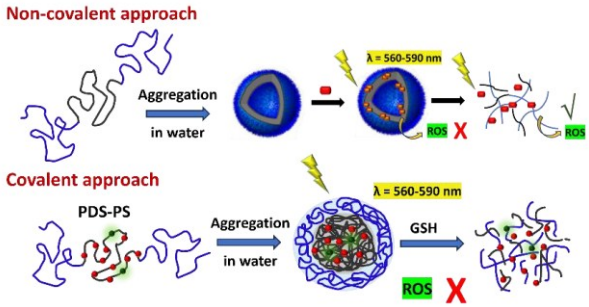


Figure 1: Schematic Representation of Activable Photosensitizer and stimuli responsive ROS generation

Keywords: Photodynamic therapy, Heavy atom-free photosensitizer, Redox-responsive polymer, Glutathione activation, Reactive oxygen species, Stimuli-responsive nanoparticles.

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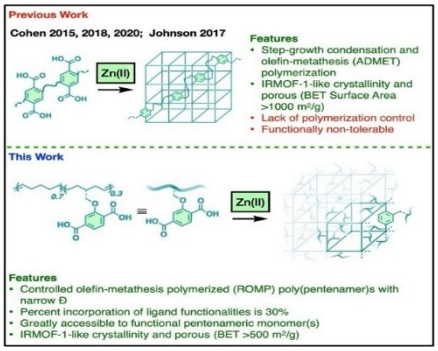
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Polymer-Metal-Organic Frameworks (PolyMOFs) based on Controlled Poly(alkenamer)s

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Polymer metal-organic frameworks (polyMOFs) are crystalline, porous materials assembled via metal ions and organic polymers containing metal-coordinating sites, exhibiting discrete physical and processability features compared to conventional MOFs based on molecular ligands.[1] Polymers with ligand units, e.g., 1,4-benzenedicarboxylic acid (H_2bdc), in their backbone, are typically employed in the design of polyMOFs.[1-3] The lack of effective methods for designing such polymeric linkers with tailor-made composition remains a significant limitation of these systems. The exploration of polymers with metal-coordinating units as pendants to prepare polyMOFs is, in contrast, rarely explored, even though the potential such systems to exploit a diverse range of chain polymerization methods.[4] Existing systems are predicated on non-living polymerized linkers bearing H_2bdc pendants that yielded polyMOFs exhibiting critical limitations in controlling polymer composition and their corresponding polyMOF characteristics. Here, a controlled olefin-metathesis polymerization was utilized to develop random copoly(pentenamer)ic linkers containing a loading of 30% H_2bdc pendants with narrow dispersity (**Figure 1**). These polymers were subsequently assembled into porous, crystalline networks with an isoreticular MOF (IRMOF) lattice topology. This controlled chain polymerization method provide access formulating polyMOFs with tailored characteristics, including tuning structural morphology and side chain functionalization.[5]



Figures 1 – *Top:* Pictorial illustration of early polyMOFs using polymers with ligand units at the backbone. *Bottom:* This report demonstrates controlled poly(pentenamer)s and their transformation into polyMOFs.

Keywords: PolyMOFs, Controlled Poly(pentenamer)s, Olefin-Metathesis

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Thermo-mechanical characterization and cure kinetics of hydroxyl terminated polybutadiene (HTPB) with energetic plasticizers

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The development of safe and high-performance energetic solid propellant formulations has gained great attention in recent years, with particular emphasis on incorporation of new and novel energetic additives to improve the performance. Among these, replacement of conventional inert plasticizers with energetic plasticizers is found to be a viable strategy for increasing the energetics of the solid propellant formulation**.** Unlike the conventional energetic plasticizers viz., dioctyl adipate (DOA), dioctyl phthalate (DOP), Isodecyl Pelargonate (IDP) etc., which are inert and do not contribute on increasing the energetics of propellants. However, energetic plasticizers which possess explosophoric groups viz., nitro (-NO_2), nitrato (-ONO_2), azido (-N_3) etc., have higher energy and oxygen balance and are found to contribute significantly to improve the energetics [1]. Energetic plasticizers viz., butyl-(2-nitroxyethyl)-nitramine (Bu-NENA) and bis(2,2-dinitropropyl) formal/acetal (BDNPF/A) (Fig 1) are promising energetic plasticizers that offer enhanced energy content and compatibility with existing HTPB binder system[2]. Though the synthesis of energetic plasticizers and their properties are reported elsewhere, a detailed study incorporating them with HTPB is not reported. In this study, a detailed thermal, mechanical, curing aspects of energetic plasticizer in combination with HTPB binder was undertaken. Thermoanalytical methods viz., differential scanning calorimetry (DSC) and thermogravimetric Analysis (TGA) were undertaken and the decomposition characteristics of HTPB-Energetic plasticizers were studied and compared with a conventional system containing HTPB and IDP. The mechanical properties were evaluated in gum stock level by curing of HTPB with a diisocyanate with an equivalence ratio (r) of 0.80. It was found that a 27- 33 % increase in elongation was observed for the HTPB-energetic plasticizer system (Table 1). Heat of combustion of plasticized HTPB were evaluated and are found to be 1200 cal/g for HTPB-IDP system, while it is 1400-1500 cal/g for HTPB-energetic plasticizer system. Thermochemical calculations of ammonium perchlorate (AP) -HTPB-energetic plasticizer propellant by NASA-CEA at 70 bar pressure with an area ratio of 10, at a solid loading of 81% shows that the specific impulse (I_{sp}) could be increased by 3-5 sec. The cure characteristics and kinetics of HTPB-diisocyanate system with energetic plasticizers were studied and activation energies and Arrhenius expressions were derived and the details are presented in the paper.

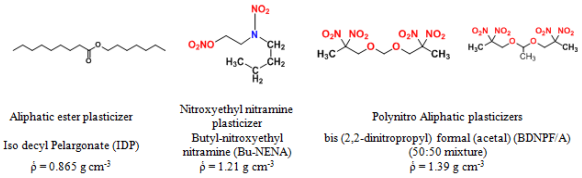


Fig 1: Structure of inert and energetic plasticizers

Table 1: Mechanical properties with inert and energetic plasticizer(R=0.80)

Gum stock Sample	T.S (ksc)		Modulus
HTPB-TDI-IDP	3.4(2.8-4.4)	**682**(570-816)	0.9(0.8-0.9)
HTPB-TDI-Bu-NENA	4.4(3.3 – 5.0)	**868**(695-949)	0.9(0.8-0.9)
HTPB-TDI-BDNPF/A	4.2(3.0 -4.7)	**911**(733-976)	0.8(0.8-0.9)

Keywords: Energetic plasticizer, solid propellant, HTPB, curing, cure kinetics

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Next-Generation Cellulosic Materials from Agro-Textile Waste: Toward a Circular Bioeconomy

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The increasing accumulation of textile and agricultural wastes presents both environmental challenges and opportunities for resource recovery through sustainable material innovation. This work explores the valorization of such lignocellulosic wastes into high-performance cellulosic materials. Cellulose is extracted using eco-friendly methods from diverse waste sources and transformed into multifunctional products. High-strength cellulosic fibers are developed with tailored mechanical and functional properties suitable for textiles and structural composites. Optically responsive cellulose films are fabricated for use in smart coatings and sensing applications. Additionally, biodegradable cellulose-based packaging materials are engineered, offering sustainable alternatives to conventional plastics with excellent barrier and mechanical properties. Porous cellulose membranes are produced for water purification, demonstrating selective filtration and antimicrobial activity. Furthermore, the inherent electrochemical properties of cellulose are harnessed to create bio-based electrodes and separators for supercapacitors, ensuring high ionic conductivity, thermal stability, and environmental compatibility. Collectively, these innovations contribute to a circular bioeconomy by converting waste into value-added, biodegradable products. This holistic approach not only reduces environmental burdens but also promotes the development of next-generation sustainable materials for applications spanning textiles, electronics, environmental remediation, and packaging.

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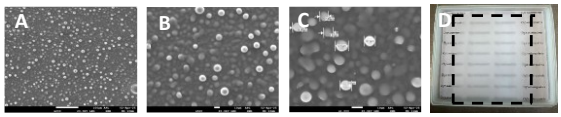
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Synthesis and Characterization of Self-Matting Acrylic Emulsion for Architectural Coating

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High-gloss coatings have long attracted attention due to their aesthetic appeal and reflective properties. However, glossy surfaces are prone to visible imperfections such as minor abrasions, oil or grease buildup, dust accumulation, and fingerprint marks, which detract from their appearance [1]. These limitations have driven increasing demand for matt coatings, which offer several practical and aesthetic advantages. Matt surfaces effectively conceal minor surface defects and require less frequent cleaning [2]. Their reduced glare minimizes visual distractions, making them particularly suitable for environments such as workplaces, educational institutions, and healthcare facilities [3]. Conventional acrylic emulsions typically yield glossy to semi-glossy finishes upon drying. To reduce gloss, insoluble particles-commonly referred to as matting agents are incorporated into the formulation [4]. Despite their effectiveness, these inorganic matting agents present several drawbacks. Their rigidity and inflexibility make them difficult to disperse uniformly within emulsions. Achieving complete wetting of these particles is essential for uniform gloss reduction, especially in dead matt coatings, which require high dosages of matting agents. This often results in uneven wetting, poor mechanical properties, and compromised aesthetics due to patchiness [5]. These challenges underscore the need for developing more compatible, dispersible, and environmentally friendly alternatives. This study presents a novel synthetic approach for developing a film-forming, self-matting acrylic emulsion *via* suspension polymerization, utilizing polyvinyl alcohol (PVA) as a colloidal stabilizer. Various grades of PVA, both individually and in combination, were employed to tailor the emulsion's particle size, viscosity, and matting characteristics. The resulting films exhibited a soft tactile feel, excellent water resistance, and a pronounced matting effect, achieving gloss levels as low as 2-20 units at 85° incident angle. Micron-sized emulsions were characterized using optical microscopy (OM) and scanning electron microscopy (SEM) all confirming the formation of spherical particles with uniform morphology. Particle size distribution was further analyzed *via* dynamic light scattering (DLS). The influence of different PVA types and ratios on surface morphology, particle size, matting effect, and viscosity was systematically investigated.



Figures 1 – (A, B, C) SEM images of matting emulsion at different magnification. (D) Visual matt effect of film on a glass plate with background "asianpaints"

Keywords: Self-matting emulsion, Polyvinyl alcohol, Suspension polymerization

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Dissolvable microneedles for the rapid delivery of drugs: Development and evaluations

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Novel drug delivery systems, exemplified by microneedles, offer a non-invasive route for critical drug administration.[1] Here, we explored the delivery of Misoprostol, a commonly used drug for labor induction, through microneedles.[2] Microneedles composed of blends of PVP10 & PVP 360 and Hyaluronic acid were fabricated using micro-molding, with Misoprostol loaded via tip loading.[3] Tip loading route was used; so as to make sure the successful and immediate drug release upon skin insertion. Scanning electron microscopy (SEM) and FTIR analysis were performed to characterize the developed microneedles. Rheological analysis of the polymer solutions was performed to optimize the microneedle formation and drying conditions. Mechanical strength of the microneedles was analysed to find that they are stable upto forces higher than that required for skin insertion; indicating their easiness to handle. *In vitro* insertion evaluations using parafilm and porcine skin were further used to validate the penetration capacity of the microneedles. Drug release studies were performed using the Franz diffusion cell and it showed an instantaneous release of drug within the first 2 min and almost complete release within 30 minutes of insertion irrespective of the dissolving polymer used. Cytotoxicity evaluation was performed on both blank and drug loaded micro needles and it was found to be non-toxic. *In vivo* evaluations were conducted in albino Wistar rats to further conform the insertion ability and dissolution rate; with almost all the drug dissolution achieved within first 5 to 10 min of insertion. Histopathological analysis also showed successful penetration on the stratum corneum with minimal and reversible tissue damage with no signs of erethma and odema indicating absence of skin irritation. The skin resealed within 24 h; indicating the safety and suitability of this drug delivery system for clinical application. Our findings suggest the potential of microneedle-based delivery of Misoprostol as a promising approach for maternal health, offering rapid, safe, non-invasive and efficient drug administration under fast and critical conditions. Further research is warranted to optimize the formulation and explore the clinical efficacy in human subjects.

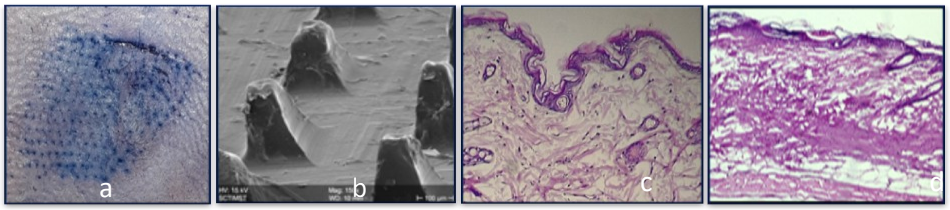


Fig.1. *In vivo* skin insertion & needle dissolution of PVP10/360 MNs for 2 min of application in rat a.) Puncture mark on rat skin. b.) SEM image of the microneedle after application) c & d) Histopathology image of rat skin after 5 min & 24 hr.

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Intumescent, Flame-Retarded Poly(urethane-imide) Copolymer Films with Enhanced Thermal Stability

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Poly(urethane-imide)s (PUIs) are an emerging class of high-performance polymers that integrate the flexibility of polyurethanes with the thermal and mechanical stability of polyimides. Compared with conventional polyurethanes, PUIs exhibit better thermal resistance and avoid dripping of molten polymer during burning, but they are still prone to ignition and flame spread. Enhancing their self-extinguishing ability is therefore essential for applications requiring strict fire safety. This study focuses on the preparation of flame-retarded, anti-drip PUI films designed for specialized high-safety uses. Copolymers were synthesized from methylene diphenyl diisocyanate (MDI), polyethylene glycol (PEG), pyromellitic dianhydride (PMDA), and a reactive phosphorus-based flame retardant, at varying additive levels to target self-extinguishment performance consistent with UL-94 VTM-0 standards, without dripping of molten material. FTIR spectroscopy confirmed successful copolymer formation. Thermogravimetric measurements showed staged degradation, with increasing char residues at higher PMDA contents. The addition of the phosphorus-containing flame retardant slightly lowered the onset of decomposition but greatly enhanced carbonaceous residue formation, pointing to a condensed-phase suppression mechanism. Microscopic analysis of the burned residues revealed swollen, porous char structures characteristic of intumescence. The combination of high thermal stability, effective suppression of flame propagation, with anti-drip properties make these PUIs as attractive candidates for advanced applications such as aerospace components, protective textiles, and insulating films where fire safety and reliability are mandatory.

Keywords: Poly(urethane-imide) (PUI), Flame retardancy, Anti-drip behavior, Phosphorus-based additive, Intumescence

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Development of Ecofriendly Food Packaging Film based on Gluten, Poly(ethylene) oxide and Chitosan

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The focus on producing ecofriendly food packaging materials that are both biodegradable and sustainable has intensified due to the environmental concern linked with conventional plastics. The use of biodegradable polymers helps in reducing carbon footprint, which in turn reduces the dependency on fossil fuels and promote sustainability. In the present research, the gluten is selected as the major polymer and is then mixed with Poly(ethylene) oxide) (PEO), to form a gluten/PEO blend which is biodegradable. The films were casted, dried and tested for mechanical properties like tensile strength, flexibility, modulus and further characterized by Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), hot stage polarizing microscopy, Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), Contact Angle Measurement, Scanning Electron Microscopy (SEM) and UV stability. The results showed that 60/40 (wt%) Gluten/PEO blend composition is better in terms of mechanical properties. Chitosan nanofiller is added to the blend to further improve its barrier properties. Tensile test revealed that blend and composite films are stronger than neat gluten film. FTIR analysis showed the variation of intensity of the peaks and band shifts indicating the interaction between the polymers. UV Vis spectroscopic studies of films showed that they are suitable packaging material for UV sensitive food products. TGA studies showed better thermal stability of composite film than neat gluten film. Thus, the developed film can be a suitable sustainable material for food packaging applications.

Keywords*:* Gluten/PEO blend, Chitosan nanofiller, barrier properties, sustainable material, food packaging.

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Chemistry as the key: Degradation mechanism of Recycled Phillips and Ziegler-Natta Catalyst HDPE During Mechanical Recycling

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The increasing accumulation of plastic waste necessitates advancements in recycling methodologies. This study examines the molecular degradation of two blow molding grade high density polyethylenes (HDPE), Ziegler-Natta-catalyzed HDPE (ZN-HDPE) and Phillips-catalyzed HDPE (P-HDPE) during mechanical recycling in a twin-screw extruder. Although both polymers exhibit identical melt-flow index (MFI), their degradation mechanisms differ significantly. The molecular modifications induced by recycling are analysed using Cross Fractionation Chromatography[1] (CFC), Temperature Rising Elution Fractionation (TREF), small-amplitude oscillatory shear[2,3] (SAOS), and extensional rheology[4]. Constitutive rheological modelling[5] is employed to interpret the degradation behaviour and optimise processing parameters such as temperature, recycling time, and screw rotation speed to facilitate HDPE upcycling. The findings indicate that the catalyst type and processing conditions strongly influence molecular degradation, characterized by chain scission, crosslinking, and branching. In P-HDPE, formation of star-like branching in shorter recycling time in both temperatures and chain scission is predominant at 170 °C, as evidenced by a reduction in complex viscosity. However, at 210 °C, branching and crosslinking occur and lead to an increase in complex viscosity and significant strain hardening in extensional flow. In contrast, ZN-HDPE undergoes a substantial reduction in molecular weight and viscosity at both temperatures, which indicates chain scission at both temperatures. The strain hardening occurs exclusively at high temperatures for ZN-HDPE. The degradation mechanisms are further elucidated through rheological modelling and incorporating molecular analysis from CFC data. These results underscore the critical role of catalyst type in determining the rheological properties of recycled HDPE and provide a framework for optimizing processing conditions to enhance its upcycling.

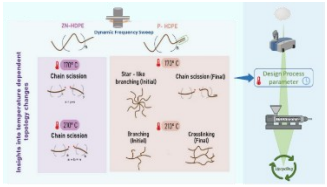


Figure 1 Path-dependent rheological evolution of HDPE during thermal–mechanical recycling: Toward rational upcycling design.

Keywords: Upcycling, Ziegler Natta and Phillips catalyst HDPE, Cross Fractionation Chromatography (CFC), Shear and Extensional Rheology and Rheological constitutive models.

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Hydrophilic Thin Film Coatings for Glass

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Thin-film polymeric coatings on glass impart a range of functional enhancements for architectural glass, solar panels and automotive glass. Depending on the end application (reducing dirt pickup, making surface self-cleaning or easy cleaning, imparting anti-smudge property or anti-fogging characteristics), these coatings are designed to be either hydrophobic/hydrophilic and or oleophobic/oleophilic. The hydrophobic coatings are generally found to have better durability on glass against environmental factors while hydrophilic coatings have lower film integrity. Further, glass substrates are prone to corrosion where leaching of alkali ions takes place due to environmental factors such as humidity, temperature, and interaction with acidic/alkaline compounds. We report ambient cured hydrophilic thin film coating on glass using sol-gel chemistry. The durability of the coating is studied using QUV accelerated weathering; surface morphology of the coating is evaluated using AFM and SEM analyses; and optical properties of the coating are measured using UV–Vis–NIR spectroscopy. The coating displays high transparency and dirt cleanability with enhanced durability. The contact angle of the coating is ~10° and sliding angle is ~6° which enhances self-cleaning property making them potential candidates for onsite installed architectural façade coatings and solar panels.

Keywords*:* glass coating, sol-gel, thin film, hydrophilic

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Synthesis And Characterization Of Azide Decorated Energetic Oxetane Hyperbranched Polymer

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Solid propellants widely used are based on hydroxyl terminated polybutadiene (HTPB) as polymeric binder in combination with ammonium perchlorate (AP) as oxidizer. For realization of advanced propellants with high performance, new binder systems are inevitable in addition to energetic oxidisers. Typical energetic binders currently used are linear polymers containing explosophoric groups such as nitro, nitrato, azido etc. However, poor mechanical properties rendered by these binders limit their application. Hyperbranched polymers with core-shell architecture possessing energetic groups such as azido, nitrato etc are found to be promising alternatives for their linear counterparts and they offer improved mechanical and ballistic properties. In the present work, an energetic hyperbranched polymer (EHBP) (Fig. 1) with polyoxetane as a core and azido-functionalized polymer as a shell is synthesized and characterized by spectral and thermal methods. The EHBP was synthesized by a three-step process which involves 1) the synthesis of polyoxetane core by cationic ring opening polymerization of 3-ethyl-3-hydroxymethanol oxetane (EHO) in presence of boron trifluoride ethyl etherate (BF_3-etherate) at room temperature.[1] 2) copolymerisation of PEHO with epichlorohydrin (ECH) at 0°C to form hyperbranched polymer viz. PEHO-co-PECH with PECH as the shell and 3) tosylation followed by azidation of ECH moieties to form the EHPB viz. PEHO-co-GAPA wherein all chlorine and hydroxyl groups of PECH are converted to azide to get azido decorated hyperbranched polymer.[2,3] The degree of branching was calculated from NMR spectroscopic data and was found to be 58.5%. The polymers formed at each stage were characterized by spectroscopic methods viz. FT-IR, ^{1}H and ^{13}C NMR.[4] The molecular weight of the polymer was determined by gel permeation chromatography (GPC) and was found to be 2140 Da. Thermogravimetric analysis (TGA) of PEHO-co-GAPA shows a two-stage decomposition with decomposition onsets at 184°C and 358°C with an overall mass loss of 80%. The major decomposition peak observed at 242.6°C corresponds to decomposition of azide groups and the peak at 406.6°C corresponds to the decomposition of polyether skeleton of PEHO-co-GAPA.

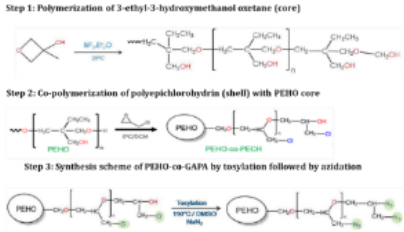


Figure 1: Scheme of synthesis of EHBP

The mechanical and thermal properties of the EHBP cured with alkyne based curing agents are elaborated in the paper.

Keywords*:* Hyperbranched polymer; cationic ring opening polymerization, polyether, azide

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A Revisit on the Morphological Switching of Stimuli Responsive Schizophrenic Copolymer and its Modern Application

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Schizophrenic copolymers, the real example of macrosurfactants, are remain at the forefront of polymer science having characteristic features such as stimuli responsiveness, interchangeable amphiphilicity, reversible core-shell alteration, and morphological switching.[1-3] The proper balance of amphiphilicity by the insertion of suitable tunable blocks into the polymer backbone (Figure 1) to have schizophrenic morphological alterations triggered by multiple environmental signals is an interesting topic of investigation that are received great attention over last two decades. This work highlights a variety of sequence regulated complex architecture, designed with free $-NH_2$ and –COOH groups in the side chains, that were capable to exhibit pH regulated morphological transitions. The calculated hydrophilic mass fractions of the synthesized copolymers at different pH are nicely correlated with the experimentally (SEM and TEM) observed nano-aggregates.[4] The pH induced substantial structural rearrangement in the polymeric architectures was confirmed by the ^{1}H-NMR spectral evidence. The reversible core-shell alteration of polymer nano-aggregates (micelle to vesicle or worm like) in aqueous media facilitates to encapsulate the drug, DOX.HCl and subsequent pH triggered release. Copolymers with different sequences and compositions having tunable hydrophilic and hydrophobic blocks should be capable of similar schizophrenic transformations and are under investigation.

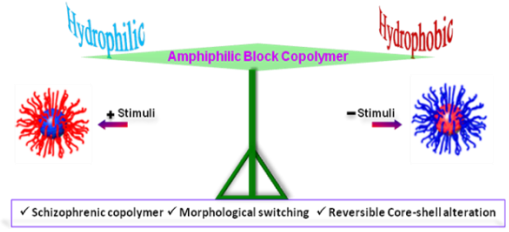


Figure 1. The stimuli induced reversible core-shell alteration of schizophrenic copolymer

Keywords: Schizophrenic copolymer, Amphiphilicity reversal, Core-shell alteration, Self-assembly, Morphological switching.

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Characterisation of EDPM/NBR Blends for Solid Motor Thermal Insulation

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EPDM (ethylene propylene diene monomer) rubber-based formulations are widely considered as thermal insulation systems for solid rocket motors [1]. The low density and improved thermal properties promote this elastomer in solid motor thermal insulation applications [2]. Meanwhile, being a non-polar rubber, the low interface adhesion, vis-a-vis rubber-to-metal and rubber-to-composite, pose problems on its use as insulation for heavy lift solid motors having case bonded propellant grains. NBR (nitrile rubber) blending with EPDM helps to induce polarity in blend matrix and improves interfacial adhesion [3].

The effect of NBR addition to EPDM on the properties of binary blend was characterised. Blend efficiency was studied by evaluating the mechanical, interface, ablative, and thermal properties. A compatibilizer system was incorporated to modify the interfacial adhesion between the rubber matrices. Blend morphology and glass transition studies were conducted to validate the compatibilizer efficiency. This blend was compounded with reinforcing/ablative fillers and tackifiers to prepare an internal insulation system for solid motors.

The mechanical properties indicate that 1 phr (parts per hundred rubber) of compatibilizer is optimum in achieving the best results. Study confirms the use of NBR in improving the properties of the blend, 90:10 (EPDM:NBR) ratio exhibits the best balance of properties. The polar rubber's effectiveness in improving the interface property and ablation resistance was demonstrated.

Thermal insulation behaviour of EPDM/NBR blend was studied using effective thermal conductivity models [4]. Among the different analytical models, the series model was found to have a good correlation with the experimental data. Accordingly, an EPDM/NBR blend based thermal insulation material was designed and tested for launch vehicle applications, **Figure 1**.

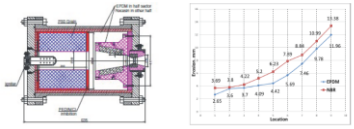


Figure 1: EPDM/NBR blend performance evaluation in a test motor

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Novel Eco-friendly Polymers for Functional Coating

Tirthankar Jana

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Protection of health, safety and environment from chemical pollutants is getting more attention across the globe. This has created a demand of environmentally benign products for high performance coating application. As a result, attempts are being made to use different non-toxic, renewable biopolymers like chitosan, cellulose, lignin, tannin etc. as an organic counterpart in combination with different polymeric materials for development of specially designed biobased functional polymer.

Among natural raw materials, chitosan performs antimicrobial activity, deodorizing, toxic metal scavenger and excellent film forming ability. However, incorporation of chitosan into any polymer matrix is quite challenging due to its low reactivity and solubility. In our study, chitosan was incorporated into modified epoxy resin system through ionic interaction followed by reaction with suitable amine hardener to form chitosan modified epoxy coating. This modified epoxy paint in the form of two component coating system can remove 90 percent of arsenic from natural ground water when coated on surface contact with water in the container. Such paint has potential for use as interior coating of water storage tank, swimming pool, water reservoir etc.

Similarly, for protection of metal against corrosion, organic coating based on toxic corrosion inhibitive pigments create environmental pollution. The use of tannic acid, a natural phenolic compound in coating formulation exhibits excellent adhesion and anti-corrosive performance on metal surface. However, it is very difficult to form a single-phase material of tannic acid in any resin system in view of its high polarity and less reactivity with resin components. To overcome this problem, tannic acid has been chemically modified with natural rosin followed by esterification with different alkyd components to form tannic acid modified alkyd. Such tannic acid modified alkyd-based coating exhibits long term anticorrosive performance as tannic acid is chemically linked with alkyd matrix. Applications of such a facile and environmentally benign route would play a key role for the development of anti-microbial, anti-corrosive and water purifier coating based on natural material to fulfil general hygiene, safety, and sustainability requirements.The presentation will deal with synthesis, characterization of such innovative polymers and their functional attributes in coating application.

Synthesis of Sulphonic-acid functionalised porous Polymer Adsorbent using Template leaching Technique for Improved Strontium uptake

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A Polymer based porous adsorbent was synthesized via template leaching followed by radiation-induced graft polymerization. Herein, a porous Polycaprolactone (PCL) was synthesised via template leaching and subsequently subjected to grafting with Glycidyl methacrylate (GMA), followed by functionalization to introduce sulfonic acid groups. Salt leaching technique was utilised to enhance porosity in the samples, in which NaCl was added during the polymer synthesis along with Trimethylolpropane Triacrylate (TMPTA) as crosslinker and subsequently salt was leached out using hot water [1]. Parameters such as salt content, leaching time and temperature were optimised to obtain maximum porosity and mechanical stability of the polymer. The critical parameters such as radiation dose, monomer concentration, and grafting percentage were systematically optimized. Comprehensive physicochemical characterization was conducted to assess functional group composition, surface charge, thermal stability, porosity, and Ion Exchange Capacity (IEC) using various analytical techniques. The synthesised adsorbent was then utilised for investigating the uptake of Sr^{2+} ion via optimising parameters such as concentration of Sr^{2+} solution, time, pH and Temperature. Langmuir, Freundlich and Temkin adsorption models were used to investigate the mechanism of adsorption and the interactions between the Sr^{2+} ion and adsorbent. Further, kinetic model fitting was performed using pseudo first order, pseudo second order and intraparticle diffusion models. Modelling results demonstrated that the Langmuir isotherm and pseudo-second-order kinetic model provided the best fit to the experimental data, highlighting the predominance of monolayer adsorption and time-dependent uptake behaviour of Sr^{2+}. Best sample with 200 % initial Salt content showed a remarkable maximum adsorption capacity of 47.6 mg/g which can be attributed to enhanced porosity and accessibility of functional group. Multiple adsorption–desorption cycles were conducted to evaluate the adsorbent's recyclability and reusability.

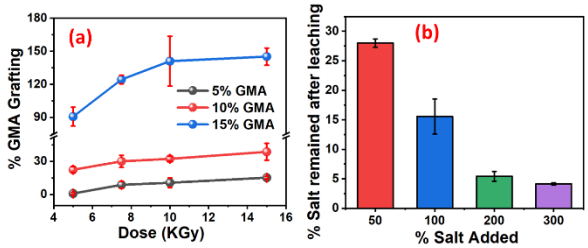


Figure 1. (a) Variation of GMA grafting percentage with % GMA and Dose; (b) Effect of % Salt leaching on initial Salt Content.

Keywords: Template Leaching, Polycaprolactone, Adsorption, Porosity, Radiation Grafting

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Microplastic Separation from aqueous media by superhydrophobic jute fabric developed using electron beam radiation

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Abstract: The accumulation of microplastics (MPs) in various aquatic environments is an alarming problem of the modern world. Hydrophobic surfaces are a potential candidate to remove MPs from water [1,2]. This work reports the development of a superhydrophobic and superoleophilic jute fabric by covalently attaching long-chain hydrocarbon molecule dodecyl methacrylate (DMA) using Electron Beam (EB) radiation. 5 MeV, 15 kW electron beam accelerator is used for the modification. Variation of surface wettability with degree of modification is studied, and the required extent of modification needed for the generation of superhydrophobicity is determined. Modified jute fabric is studied thoroughly using various characterization techniques, namely, FTIR, SEM, water contact angle measurement, tensile testing, etc. Modified jute fabric shows very high water contact angle of 150°. Study of tensile testing and surface morphology reveals no alteration of the basic structure and properties of jute fabric due to modification. Modified jute fabric is then employed for separating common MPs (HDPE and LDPE) from water, and successful separation is demonstrated. The effect of different oily phases on separation efficiency and removal is studied. In the presence of oily solvent phase, instantaneous and highly efficient (>95%) separation of MPs from water is demonstrated, as the MPs are accumulated in the organic phase. Removal efficiency and reusability of the modified jute fabric are found to be satisfactory. This simple on step, environment-friendly process of preparation of superhydrophobic superoleophilic jute and its application in separating MPs may be a sustainable solution for MP-related environmental issues.

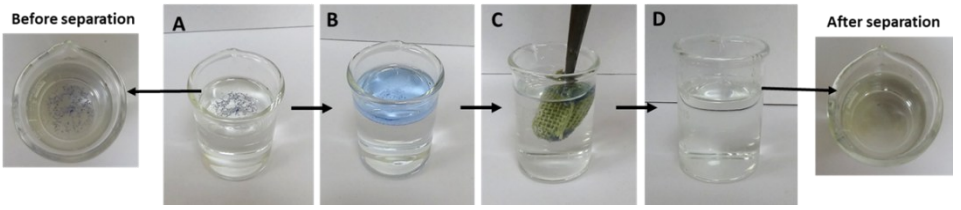


Figure 1. Separation of microplastics from water using modified jute fabric (A-D)

Keywords: microplastic, separation, superhydrophobic, natural polymer, waste management

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Development of sustainable gas sensors using green polymer nanocomposites for environmental monitoring

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Ammonia (NH_3) is a toxic, water-soluble gas produced more than 100 million tons globally. This versatile compound finds its way into numerous fields, playing key roles in chemical production, food science, agriculture, refrigeration, and clinical diagnostics.1 Exposure to ammonia (NH_3) can pose significant health risks, starting at concentrations as low as 50 parts per million (ppm), which can cause irritation to the eyes, nose, respiratory tract, and skin.2,3 At 500 ppm, the danger escalates dramatically, leading to severe complications like fluid accumulation in the lungs and chemical bronchitis. This alarming potential for destruction has sparked an increasing demand for low-level NH_3 gas sensors. These sensors are essential for preventing overexposure and can provide vital health alerts to keep individuals safe. To address this problem, we have successfully developed a sustainable gas sensor designed for detecting ammonia gas at room temperature, utilizing environmentally friendly materials. MoS_2 is a transition metal dichalcogenide (TMD) that, in the form of nanosheets, is a potential material in the field of gas-sensing due to its large surface-to-volume-ratio.4,5 Our innovative sensor utilizes liquid-exfoliated MoS_2 nanosheets combined with biodegradable polymers, including Polyvinyl alcohol and Polyethylene glycol. When exposed to NH_3 gas, this new sensor exhibits a significant reduction in resistance, confirming its N-type behaviour and demonstrating its high sensitivity and selectivity. The sensor exhibited a remarkable response of 385% in the presence of 50 ppm NH_3 gas at room temperature, accompanied by rapid response and recovery times of 8 seconds and 7.5 seconds, respectively. It also exhibited excellent reproducibility and impressive selectivity against various gases at room temperature. These findings highlight the potential of these MoS2 based green polymeric gas sensors as a promising material for enhanced and selective NH_3 gas monitoring under ambient conditions.

Keywords: Sustainable, metal chalcogenide, gas-sensors, n-type semiconductor, nanocomposites

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Recent trends in carbon fiber research: Manufacturing

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Abstract: Carbon fibers have exceptionally high mechanical strength and stiffness. Polyacrylonitrile (PAN) precursor-based carbon fibers exhibit tensile strength up to 7 GPa. However, the process relies on costly, non-sustainable petroleum sources. Developing a process to synthesize acrylonitrile from biogenic material such as glycerol would be more environmentally friendly, as it emits lesser CO_2 [1]. Thermal conversion of PAN precursor fibers into carbon fibers, especially the carbonization step in the conventional heat treatment line, is a high-energy-consuming and slow-heating process. Alternative heating strategies, such as microwave heating can make the process, energy efficient and faster. However, the precursor fiber needs a surface change, such as susceptor nanocoating, as it does not absorb microwaves [2]. Thermo-oxidative stabilization before carbonization is another complicated and time-consuming step during the heat treatment process. Plasma irradiation-assisted modification of the precursor fiber could introduce more oxygen-containing groups, thus shortening the stabilization time and making the heating process faster [3]. PAN-based carbon fibers are mostly used in high-tech sectors like aerospace as the making of precursor fibre accounts for ~50% of total carbon fibre production cost. Alternative precursors made from renewable feedstock like wood mass-sourced lignin could improve the sustainability of the process and reduce the production cost [4]. Cellulose is another abundantly available biopolymer with a long history as a carbon fiber precursor. However, cellulose-derived carbon fibers exhibit poor mechanical strength. Improvising strategies, such as controlled stabilization or carbonization aids, can improve the fiber strength [5]. Researchers have also tried blending lignin with cellulose, PAN, and other polymers like polyvinyl alcohol to make cost-effective carbon fibers. The alternate precursor route would lower the carbon footprint compared to traditional PAN-based carbon fibers; however, scaling up the process from laboratory scale to the pilot or industrial scale is the key challenge in developing carbon fiber process technology.

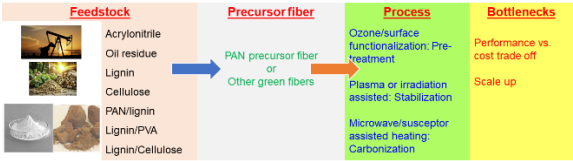


Figure 1 – Recent trends in carbon fiber research

Keywords: Carbon fibers, polyacrylonitrile, lignin, cellulose

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Enhancement of Abrasion Resistance in Acrylonitrile Butadiene Rubber (NBR) Composites Using Carboxylated NBR Blends

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Nowadays, acrylonitrile butadiene rubber (NBR) has been applied to various products and equipment to serve industrial production and human life. These include products that are resistant to oil and chemical environments, especially with high wear resistance [1-3]. In this study, composites of acrylonitrile butadiene rubber the abrasion resistance efficiency of graphene as a filler in elastomeric composites and compares its performance against conventional fumed silica systems and Mixed Metallic Filler – Industrial Waste Sludge. Incorporation of 1 phr of graphene demonstrated comparable compounded and ageing properties to those obtained with 40 phr of fumed silica, highlighting graphene's superior reinforcement potential. Graphene-based composites exhibited marginally enhanced absionsion resistance relative to silica-based. To further improve the abrasion resistance of NBR based compound, NBR having higher ACN content is blended with carboxylated NBR. This grade exhibited 25–35% higher tensile strength compared to normal NBR grade with all the three fillers. Overall, the results underscore the potential of blended NBR and carboxylated NBR based system especially for the application where high abrasion resistance is required i.e., Rice Roller application, which is used in rice mills for separating husk from rice and also in Cots & Apron in textile industries.

Keywords: Carboxylated NBR; Rubber Blend; Abrasion resistance; Rice Roller

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Therapeutic Role of Folic Acid–Ceria Nanoparticles in Antibacterial Wound Management

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In patients with diabetic foot ulcer and other chronic wounds would be nowadays a major cause of death worldwide. The advanced nanotechnological paradigm leading to useful technology for customizing the pharmacokinetic characteristics of various drug delivery systems[1]. This study investigated the potential effectiveness of folic acid (FA)-functionalized nanoceria (FA-nanoceria) in the wound healing process. The nano formulation produced an impressive bacteriostatic effect when applied to both Gram-positive and Gram-negative bacteria. Folic acid (FA) was used to chemically functionalize nanoceria, which had a zeta potential of -20.1 mV and a particle size of 10–20 nm. The use of UV-Vis spectroscopy was utilized to verify for FA on the nanoceria's surface, and FTIR spectroscopy was employed to validate FA-nanoceria synthesis. To validate its potential therapeutic efficacy as a wound dressing material, the antimicrobial study and cellular biocompatibility were assessed. Further to monitor the wound healing cascade in vivo experimental model has been set up and investigated at different days intervals. The underlying cause for these findings is associated with the penetration of the bacterial cell wall leads to the formation of intracellular reactive oxygen species (ROS), modulating the bacterial enzymes, DNA, RNA, and protein, ultimately leading to bacterial cell death[2]. Oxidative stress and bacterial cell disruption are also caused by the redox state transition (Ce^{4+} to Ce^{3+}) that occurs following absorption on the cell surface. FA-nanoceria is a potential therapeutic agent as a special spray formulation in wound healing applications because of the combination of antioxidant and reactive oxygen species scavenging activities of both the FA and nanoceria[3]. The nanoformulation exhibited both biocompatibility and bacteriostatic activity towards several cell lines. In a Wister rat model, a 0.1% w/v spray of FA-nanoceria showed a remarkable ability to heal wounds in just 14 days. This FA-nanoceria might potentially be used to reduce ROS production caused by bacterial endotoxins. By effectively assisting in the closure of the wound due to the synergism between the antioxidant property of FA and the redox-activity of nanoceria, mimicking functional properties of the synthesized nanoformulation further accelerates the therapeutic utilization as a potent wound dressing candidate for various biomedical applications.

Keywords: Nanoformulation, FA-nanoceria, ROS, Wound healing

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Evaluation of different biomaterials for application in tyre

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The incorporation of renewable biomaterials into tyre tread compounds offers potential benefits in sustainability, cost, and performance. In this study, various biomaterials including starches (maize, wheat, rice, cassava), cellulosic materials (microcrystalline cellulose and sodium carboxymethyl cellulose), soy protein, and lignin were introduced at a 10 phr loading into a silica-filled tyre tread formulation, and their effects on cure behavior and mechanical properties were evaluated. Wheat starch, cassava starch, lignin, and soy protein accelerated vulcanization, indicating their potential as bio-accelerators. Wheat starch increased tensile strength by 7.6 % relative to the control, while soy protein achieved an 11.1 % increase in tensile strength and a 10.2 % improvement in elongation at break. No significant deterioration in other compound properties was observed for any biomaterial. Overall, the combined improvements in cure kinetics and mechanical performance suggest that wheat starch and soy protein are promising sustainable additives for silica-filled tyre tread compounds.

Keywords: Biomaterials, Bio-accelerators, Tyre Tread Compound, Cure Kinetics, Composite, Sustainability, Mechanical Properties

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Impact of defects and various functionalization concertation of graphene on hydrogen diffusion

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In a hydrogen storage tank, secure and reliable storage of hydrogen gas is vital for both safety and performance. Choosing the liner material appropriately is crucial to prevent hydrogen leakage and to provide structural integrity. Researchers utilize various materials with different forms of graphene, to achieve optimal performance. Graphene with its high surface area & layered structure is a lightweight material, providing impressive mechanical strength, along with thermal stability. These properties enhance hydrogen adsorption, prevent gas leakage, and maintain structural integrity under varying pressures and temperatures, making it a promising filler material. This work examines the effects of two defect types: Thrower-Stone-Wales defect and vacancy defect with varying concentration of functionalization. In this study, an atomistic scale simulation has been employed to investigate the potential of such filler material as a liner for storage tank applications. Fractional free volume (FFV), and diffusion coefficient have been studied using molecular dynamics (MD) simulations which provide insights of critical parameters: material porosity and gas permeability, followed by mechanical and thermal stability in continuum scale simulations revealing insights at different stresses and temperatures. Various environmental conditions (especially nominal working and refueling scenarios) have been considered in this work to examine the filler material behaviour. However, it is elucidated that the diffusion of hydrogen has greatly been influenced by the presence of defects and functionalization concentration.

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Tuning of Electron Beam Irradiation Parameters on the Performances of Green, Sustainable and Water born Polymeric Hybrid

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The polyvinyl alcohol (PVOH) and polyethylene glycol (PEG) blend materials have been studied with property development for various applications. In the last decade, the gamma radiation exposure to PVOH-PEG blends has been studied well in particular for biomedical and drug delivery applications. In our investigation, PVOH-PEG (Mw:4000) green materials have been developed in aqueous medium for 90/10, 80/20, and 70/30 blend compositions and thin films are fabricated by solution casting of different thicknesses. The optimum PVOH-PEG blend composition PVOH-PEG (80/20), has been treated by an electron beam (EB) for different dose rate of 1kGy, 5kGy and 10kGy per pass. PVOH-PEG (80/20) composition optimized at 1kGy/pass dose rate is further crosslinked by electron beam for various doses by 10, 20, 30, 40, and 50kGy. The pure, unirradiated and EB irradiated PVOH-PEG samples have been subjected to examine the degree of crosslinking, mechanical, structural, surface contact angle and morphological properties. The results for the mentioned properties suggest that crosslinked PVOH-PEG (80/20) blend optimized at 1kGy/pass can be suitable for packaging and biomedical applications.



Figure: The increase of hydrophobicity in PVOH: PEG/80:20 hybrid after Electron beam irradiation optimized at 1kGy/pass dose rate

Keywords*:* Green material, PVOH-PEG blend, Electron beam, dose rate and hydrophobicity

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Synthesis and Induction of Helical Polymers and their Application in Enatioseparation

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Natural biomacromolecules, i.e., DNA, proteins, and polysaccharides with helical self-assembly, operate the most sophisticated functions, i.e., molecular recognition, replication, and catalytic activity at the molecular level. Inspired by the intriguing function of helical conformation1,2 here we have synthesized chiral polyelectrolytes having proline as a chiral pendant. Initially, the polymers contain chloride as a counter anion, shows a null absorption both in circular dichroism (CD) and UV-absorption spectroscopy. Interestingly, after the replacement of the chloride ion with the hydroxide ion, it shows a sudden transition to helical conformation, which is supported through SEM, TEM, and CD absorption spectroscopy. At the same time, substitution of chiral prolines (both L- &D-) as counter anion also behaves in the same line as that of hydroxide. Here, the study concludes, despite chiral and achiral counter anion, the polymers show their helical sense according to the attached chiral pendant, specifically L-proline substituted polymers showed a right-handed helical sense and D-proline substituted polymers showed a left-handed helical sense. Further, we changed the chain length between the chiral pendants to the polymer main chain, where we have observed that there is a decrease in helical sense by increasing the distance of the chiral pendant from the main chain. The study indicates that by increasing the distance of the chiral pendant, the chiral transformation decreases significantly.3 Then, we studied chiral amplification by synthesizing a copolymer of an achiral polymer (chloride as counter anion) with a helical polymer (hydroxide as counter anion). Interestingly, we have observed that in the presence of 1 % of helical polymer, the copolymer shows an induction of helical sense, whereas in the presence of 50 % helical polymer, the copolymer shows a complete helical handedness that of 100 % helical polymer. Here, the chiral amplification follows the conventional sergeants and soldiers rule, as the achiral polymer follows the helical sense of the chiral polymer.4,5 At the end, enatioseparation study was carried out using the helical polymer. The helical polymers show a 90 % ee up to 60 % yields.

Keywords: Chiral Polymers, Polyelectrolytes, Proline, Helix, Enatioseparation

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Carboxymethyl Cellulose Based Biopolymer Electrolyte with Hybrid Fillers for Dye Sensitized Solar Cell

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The aim of the present study is to evaluate the potential of both the use of zinc oxide (ZnO) nanoparticles as primary filler and graphene as secondary filler in carboxy methyl cellulose based polymer electrolyte. The films were characterized structurally and morphologically by X-ray diffraction (XRD), Fourier-transform infra-red spectroscopy (FT-IR), scanning electron microscopy (XRD). XRD results showed that ZnO nanoparticles inclusion reduced the crystallinity of the prepared biopolymer electrolyte. Addition of graphene as secondary filler further reduced the crystallinity of the prepared biopolymer electrolyte film. The FTIR technique and SEM images confirmed the complexation of salts with the polymer matrix. Due to graphene's ability to create conductive layers, the inclusion of a little amount of it as a supplementary filler increased the A.C. conductivity from 1.63×10^{-5} to 2.6×10^{-4} S cm^{-1}. The synergistic effects of both fillers contributed to raising the polymer electrolyte film's electrical conductivity. Utilizing this polymer electrolyte layer enabled the creation of a solid state DSSC with an efficiency of 2.6%.

Electrolyte system	V_{oc}, V	I_{sc}, mA cm^{-2}	ll Factor (FF), %	Efficiency, %
ZnO filler/Graphene: LiI : I_2	0.75	6.5	53	2.6
ZnO filler: LiI : I_2	0.6	5.3	52	1.65

Keywords: Dye sensitized solar cell, polymer electrolyte, carboxy methyl cellulose, zinc oxide nanoparticles, graphene

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Waste Polystyrene to Styrene Monomer: Unlocking Circular Value via Chemical Recycling

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Introduction

Plastic, the ubiquitous material, is projected to grow at healthy rate in the years to come [1]. However, to save the mankind and mother earth from waste plastic pollution is a challenge and requires sustainable and tangible circular solution. For the different type of waste plastics i.e polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), mechanical or chemical recycling route are generally used. However, mechanical recycling deteriorates the quality of plastic and recycled plastic doesn't possess same property like virgin plastic while in chemical recycling the waste plastic can be converted to its monomer. These monomers are again polymerized to produce plastic having properties similar to virgin polymers. Hence, chemical recycling of the pastic is gaining momentum and is expected to grow at a CAGR of 9.4% [2]. Polystyrene and Expanded Polystyrene (commonly known as thermocol) are commonly used as packaging material for electrical appliances, food trays, cups, cushioning materials for fix boxes and fragile items etc [3]. Chemical recycling of waste polystyrene is promising route to handle the problem of waste polystyrene as it can be converted back to its monomer thus providing a circular solution for its reuse without compromising the product properties unlike mechanical recycling.

Work done

In the present work, a catalytic process is developed to convert waste polystyrene to styrene monomer. Experiments were carried out for the thermal and catalytic pyrolysis of waste polystyrene to convert it into styrene monomer. The waste polystyrene was outsourced from the local aggregators. The pyrolysis experiments were carried out in batch reactor under N2 environment, at different temperature, with or without catalyst. Catalytic pyrolysis experiments were carried out using in-house developed catalyst, to improve pyrolysis oil yield and styrene monomer selectivity.

Result & Discussion

The results for the thermal and catalytic pyrolysis experiments are shown in Figure 1. The catalytic pyrolysis results in 90% yield of pyrolysis oil, which is around 10% higher over thermal pyrolysis and also around 8% higher styrene selectivity than thermal pyrolysis. The catalytic pyrolysis also requires lower residence time as compared to thermal pyrolysis. The synthesized catalyst was characterized by X-ray Diffraction (XRD), N2 physisorption technique while the pyrolysis oil was analyzed by Gas Chromatography (GC).

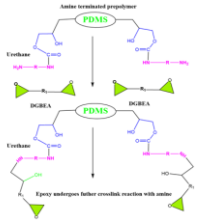
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Hybrid Polyhydroxyurethane-Sil (HPHU-sil) Coatings for Sustainable High-Performance Corrosion Protection

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Polyurethanes are widely employed as anticorrosion coatings owing to their excellent mechanical strength, abrasion resistance, and durability; however, their reliance on toxic isocyanates and phosgene poses significant health and environmental concerns. Non-isocyanate polyurethanes (NIPUs) provide a sustainable alternative, eliminating hazardous precursors. In this study, hybrid polyhydroxyurethane-sil (HPHUrSil) coatings were developed using carbonate-functionalized polysiloxanes synthesized *via* CO_2 cycloaddition of epoxy–polysiloxanes, followed by amine termination. The resulting prepolymers were cured with three commercial epoxy systems (PG1, PG2, PG3) (scheme 1). Comprehensive evaluation of thermal, mechanical, morphological, and electrochemical properties revealed that the di-epoxy cured system (PG1) exhibited superior adhesion (57 ksc), tensile strength (70 ksc), and elongation (15%), with excellent chemical resistance and thermal stability up to 300 °C. Electrochemical impedance spectroscopy demonstrated sustained barrier performance (10^8 Ω after 20 days in 3.5% NaCl) for PG1, corroborated by uniform morphology in SEM analyses. Outdoor exposure tests (MS coupons, ASTM G50-10) confirmed long-term corrosion resistance with no visible degradation after six months in a marine environment (fig.1). These findings establish HPHUrSil coatings as robust, sustainable, and highly effective candidates for anticorrosion protection of metallic substrates.



Scheme1. Reaction of PDMSCC terminated pre-

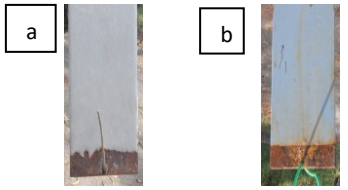


Fig.1. MS coupons coated with (a) PEG1 ands (b) Commercial epoxy after 6 months exposure to

Keywords: Sustainable, HPHUrSil, coating, EIS, Polysiloxane

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Nanofibrous scaffolds integrated with yttrium oxide nanoparticles and lysine for modulating cell adhesion, proliferation, and antimicrobial efficacy in vitro wound healing

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The complex nature of chronic wound healing, along with numerous challenges such as infections, impaired cellular activity, and disruptions in the healing process, presents a major concern in healthcare. A key barrier to effective and rapid wound recovery is insufficient cell proliferation and adhesion [1]. This issue can be addressed by using bioactive scaffolds that promote cell migration and attachment by stimulating natural cell growth, thereby aiding tissue repair. Metal oxide nanoparticles, such as yttrium oxide (Y_2O_3), offer promising potential in advancing chronic wound treatments by enhancing cell growth within scaffolds. To explore this, Y_2O_3 nanoparticles were synthesized and incorporated into polyvinyl alcohol (PVA) nanofibrous scaffolds. Additionally, lysine was added to improve the scaffolds' cell adhesion and antimicrobial properties. The structure and morphology of the fabricated nanofibers were validated using various physicochemical analyses. All scaffolds showed well-regulated water vapor transmission rates (WVTR) between 2000 and 2500 g/m²/day, optimal for removing wound exudate and promoting healing [2]. The scaffolds demonstrated strong antimicrobial activity, with up to 68% and 72.2% effectiveness against *E. coli* and *S. aureus* at optimal Y_2O_3 concentrations. They also inhibited biofilm formation by 68.6% for *S. aureus* and 51.2% for *P. aeruginosa*, reducing the risk of recurring infections. Furthermore, the scaffolds showed excellent blood compatibility, supported cell growth and adhesion, and exhibited antioxidant properties in reactive oxygen species (ROS) inhibition tests [2]. Wound healing potential was further confirmed in scratch assays, where the yttria-loaded PVA/lysine scaffold (S3) encouraged extracellular matrix development and cell proliferation. Flow cytometry and immunocytochemistry revealed a ~19.48% increase in collagen I (Col-I) expression in fibrocytes, indicating active wound repair. In conclusion, the study presents a promising approach to wound care using these multifunctional nanofibrous scaffolds, highlighting their therapeutic potential in chronic wound management.

Keywords: Yttrium oxide, lysine, antibacterial, cell proliferation, wound healing, collagen expression

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Novel Multi-Layered Functional Gels

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Multifunctional multilayer gel architectures are gaining increasing attention as next-generation materials for advanced engineering and biomedical systems, owing to their capability to combine multiple functional attributes within one integrated structure. However, conventional fabrication techniques remain complex and multistep, often producing weak interfaces between layers that deteriorate under mechanical stress, thereby limiting long-term performance.

In this work, we introduce a simple yet highly controlled one-step heterogeneous polymerization strategy for constructing robust bilayer and trilayer hydrogel systems with built-in functional gradients. The process employs uniformly dispersed, water-compatible nanomaterials embedded within a continuous polymeric network, which effectively eliminates the problems of poor interfacial bonding and structural discontinuity. As a result, the resulting gels exhibit outstanding mechanical strength, enhanced interlayer adhesion, and seamless integration of diverse functionalities across the material.

This versatile synthesis route can be adapted to numerous polymer matrices and functional nanofillers, opening opportunities for flexible and stretchable electronic platforms. Representative demonstrations include electrolyte-integrated supercapacitors with conductive gel electrodes, soft wiring systems mimicking conductor-insulator designs, and mechanically resilient sensors that couple toughness with functional differentiation. Overall, this approach offers a significant step toward scalable, multifunctional, and structurally coherent gel-based materials for emerging technologies in energy, healthcare, and soft electronics. [1]

Keywords: Multilayer gels, Functional hydrogels, Macroscopic layers, Soft electronics, Spatial arrangement

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Synthesis Of Green And Biosurfactant Derived Amphiphiles Encapsulated Metal Oxide Nano Hybrids As Nano Seed Priming Agent For Sustainable Agriculture

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Biosurfactant based biostimulants plays a vital role in agriculture filed by enhancing the soil quality, promote plant growth, and eliminate plant pathogens, and increasing nutrient uptake. This works describes the synthesis of green surfactant and bio surfactant based trimesic based lithocholic ester functionalized amphiphiles (TMLCEA) with oppositely charged head groups using thiol-yne click chemistry, which is an effective and simple approach. The trimesic based lithocholic ester functionalized zwitterionic penicillamine (TMLCEPA), cationic cysteamine·HCl (TMLCECy), and anionic thiomalic acid (TMLCETM) exhibited hierarchically self-assembled microstructures from below to above the CMC. In below the CMC, TMLCEPA, TMLCECy, and TMLCETM showed a bundle of petals, flower-like morphology, and grass seed-like patterns respectively. The morphology of self-assembly was studied by FESEM, DLS, OPM, contact angle, and zeta potential measurements. Among these amphiphiles, TMLCECy exhibited potential antimicrobial activity at above the CMC. The biostimulant effect of different concentration of TMLCEA treated with maize and green gram seeds were evaluated under *in vitro* condition, wherein TMLCECy showed improved seed germination and seedling parameters at 750 µL/mL as compared to TMLCEPA, TMLCETM and untreated amphiphiles as control. Molecular docking and molecular dynamic simulations show that TMLCEPA and TMLCETM showed higher binding affinity for dengue methyltransferase protein. The result of the present study opens up new avenues for bile acid-based amphiphiles as bio-based and cost-effective biostimulants for sustainable agriculture.

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Mucus-Mimetic Synthetic Hydrogels: A Protective Barriers for Cells against Broad-Spectrum Pathogens

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Mucus is a dynamic biological hydrogel, exhibits unique biophysical properties and forms a barrier protecting cells against a broad spectrum of pathogens. Establishing a synthetic model system that can emulate the properties and functions of native mucus is essential for understanding the complex biological functions of mucus.[1] Here we developed a polyglycerol sulfate-based dendronized mucin-inspired copolymer (MICP-1) with ~10 % repeating units of activated disulfide as cross-linking sites. Cryo-EM analysis of MICP-1 reveals an elongated single-chain fiber morphology. MICP-1 shows potential inhibitory activity against many viruses such as HSV-1, SARS-CoV-2 (including variants such as Delta and Omicron) and RSV. Inhibition activity depends on their chain length as well as different pendant functional groups.[2] MICPs appeared as highly cytocompatible in different cell lines (HBE, A549 and Vero E6), they showed negligible anticoagulant activity and complement inhibition activity. MICP-1 produces hydrogels with viscoelastic properties similar to healthy human sputum and with tuneable microstructures using linear and branched PEG-thiol as cross-linkers.[3] Single particle tracking microrheology and Cryo-SEM were used to characterize the network structures. The synthesized hydrogels exhibit self-healing properties, along with viscoelastic properties that are tuneable through reduction. A transwell assay was used to investigate the hydrogel's protective properties against viral infection against HSV-1. Live-cell microscopy confirmed that these hydrogels can protect underlying cells from infection by trapping the virus, due to both network morphology and anionic multivalent effects. Synthesis, biophysical properties and virus trapping properties of the mucus-mimetic hydrogels will be highlighted in the presentation.

Keywords: Synthetic mucus, Cryo-TEM, SARS-CoV and RSV inhibition, Healthy sputum, Transwell assay

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Efficient Triplet Harvesting via Hot Exciton Utilization in Solution Processed OLEDs Employing Tetraphenyl Buta-1,3-Diene Based AIE Emitters

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High photoluminescence quantum yield (PLQY) especially in solid-state together with harvesting radiative triplet excitons are essential to achieve efficient organic light-emitting diodes (OLEDs). Herein, the aggregation induced emission (AIE) active tetraphenyl buta-1,3-diene (TPB) moiety has been employed and tactfully modified to obtain orthogonally oriented donor-acceptor (D-A-$\boldsymbol{\pi}$-A-D) type derivatives (namely, TPB-CHO-TPA and TPB-CN-TPA) which possess additionally the hybridized local and charge transfer (HLCT) type excited-state. Moreover, computational studies have revealed the possibility of triplet harvesting through hot exciton mechanism in these designed emitters. These key features along with excellent solubility in most of the organic solvents have encouraged to utilize these as light emitting materials for solution processed non-doped and doped OLED devices. The optimal OLED device using TPB-CHO-TPA exhibits yellow light emission (ELmax = 572 nm and CIEx,y = 0.48, 0.51) having maximum external quantum efficiency (EQEmax) of 7.6% with power and current efficiency of 6.1 lmW−1 and 8.9 cd A−1 where the calculated exciton utilization efficiency (EUE) approaches to 97%, indicating efficient triplet harvesting in electroluminescence process. This work signifies a novel design strategy for AIE-based HLCT type emitters having efficient hot exciton utilization which can pave the way for future development of TPB based highly efficient OLED devices.

Keywords*:* Aggregation induced emission, hybridized local and charge transfer state, Hot exciton utilization, Organic light emitting diode, Solution processability

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Bismaleimide film adhesives withstanding both low and high temperature (-196°C to 250°C); preparation and properties

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Bismaleimide chemistry transformed into unusual film adhesives *via* unconventional combination of materials. Bismlaimides are known for their brittleness and find applications in niche areas of aerospace where high temperature matters (1-4). However, low temperature adhesive applications are rarely investigated in the outline of film adhesives in particular. BMI film adhesives capable to perform at liquid nitrogen temperature and high temperature of 250 °C are latest. By suitably toughening, film adhesives were achieved which offered T_g 240-250 °C. Toughening of 4, 4'-bismaleimido diphenyl methane (BMPM) is completed by chain extension reaction with 2, 2'-diallylbisphenol A, through the incorporation of reactive core shell rubber particle (CSR) and also by the addition of polyimide. Introduction of epoxy resin increased the adhesive properties at different temperature conditions. Effect of epoxy resin on T_g and thermal properties were correlated to the control BMI co-cured network. The BMI film adhesive exhibited lap shear strengths of 12 MPa at -196 °C, 15 MPa at 30 °C, 23 MPa at 200 °C, and 13 MPa at 250 °C. The adhesive retains 86% of its original strength even at 250 °C. These new BMI film adhesives open avenues, which can withstand both high temperature and liquid nitrogen environment, in cutting-edge technological fields.

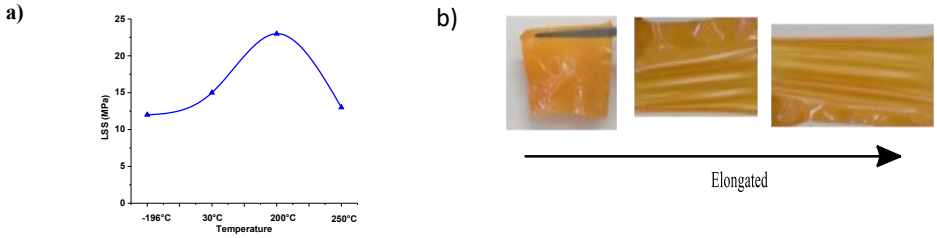


Figure 1 a) Adhesive strength of BMI film adhesives from -196°C to 250°C b) BMI adhesive films

Keywords: Bismaleimides, film adhesive, adhesive strength

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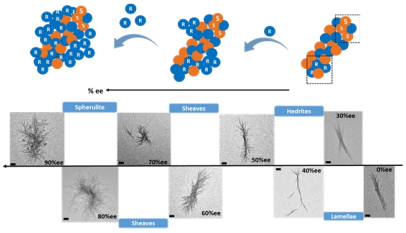
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Engineering Pseudoracemic Surface for Controlled Synthesis of 3D-Supramolecular Topologies

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Dynamic supramolecular polymers, which share functional traits with traditional covalent polymers and exhibit adaptive, self-repairing characteristics similar to biological assemblies, have become highly promising systems for designing smart soft materials. Recent progress in understanding their mechanisms and developing new synthetic approaches, such as living supramolecular polymerization, has greatly improved our control over the primary structure of these polymers. However, to fully harness their functional potential, it is essential to broaden their topological diversity, comparable to that of classical polymers, and achieve precise molecular organization across higher levels of self-assembly. Until now, molecular dynamics has primarily yielded either narcissistically self-sorted conglomerates or, in rare cases, supramolecular racemates that allow for social sorting.[1] In this work, however, we present a unique molecular design that achieves a delicate balance between homochiral and heterochiral interaction energies, resulting in a supramolecular pseudoracemate. This pseudo-racemic system effectively leverages chirality-controlled surface-catalysed nucleation, enabling precise control over secondary fibrillization and the formation of supramolecular spherulitic structures using enantiomeric excesses. This innovative approach enables control over both primary elongation and secondary nucleation through a stereoselective seeding process. Thus, chirality has been meticulously utilized to harness an ultimate control over supramolecular 3D topology which was previously unachievable.



Figures X – Schematic illustration to show chirality-controlled formation of supramolecular spherulites.

Keywords: supramolecular polymerization, secondary nucleation, spherulites, pseudoracemates, chirality.

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Rigid Poly(urethane Urea) Foams using amine-based polyol: Novel blending methodology for controlled foaming

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Polyurethane Ureas are a class material which mixes both polyureathane and Polyurea combinational effects. Amine initiated polyether polyols can be used for the production of Poly Urethane Urea (PUU)foam. This polyol contains tertiary amines and it acts as a catalyst for the reaction with polyisocyanate and water. This inherently eliminates the use of any additional amine catalyst or metal catalyst in the formulation. Amine based polyol reacts with polyisocyanate together with water to give poly(urethane-urea) (PUU)[1], The formulation is water based devoid of any physical blowing agent making the resultant foam free of any volatile emissions viz, residual mass loss (RML)<1%, hence proving to be a potential material for space craft applications.To understand the effect of two different types of amine-based polyol two different types, one with toluene diamine initiator(Polyol-L)and one with ethylene diamine initiator(polyol-H) were selected. Both polyols have different amine content hence differ in the catalytic activity. Both the polyols were used as stand-alone (SCF-01 and SCF 10) and hybrids in 1:3, 1:1 and 3:1 ratio (SCF13, SCF22, SCF31). The resultant foams were characterized by FTIR, TGA, DSC and SEM.Based on the experiments and characterization of the foams to achieve crack free, low outgassing foam ,SCF31 formulation was chosen as an optimized hybrid formulation which have no cracks,lower cell size176-250μ[2,3],low density of 47.25 kg/m^3,lower thermal conductivity[2]0f 0.038 W/m.K and better compressive strength (2.5 kgf/cm^2) and thermal stability[4](40% weight loss at 333 °C) and lower volatile emission for possible satellite applications.

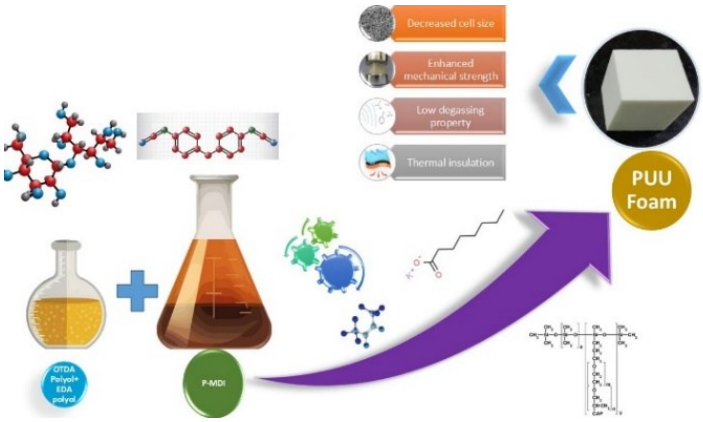


Figure 1 -Graphical abstract of the work

The following Figure illustrates that SCF-10 and SCF-31 have no cracks indicates controlled foaming.



Figure2 -Observation of PUU foam after cutting

Polyurethane and Polyurea linkages were assessed through FTIR as in Fig3

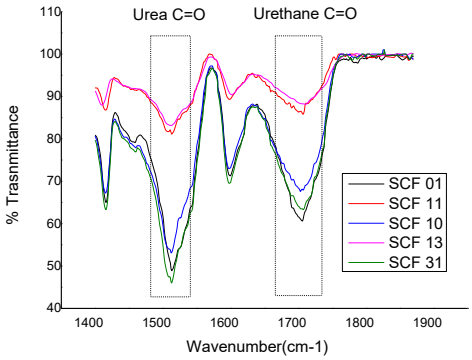


Figure3 -IR spectrum of different PUU formulation

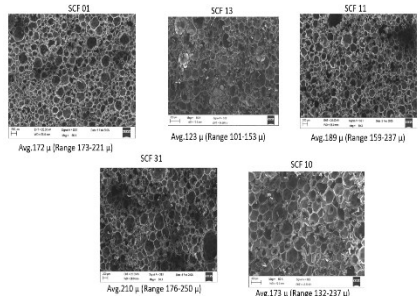


Figure3 -SEM analysis of PUU foam

Table 1: PUU foam properties at different formulation

Properties	***SCF01***	***SCF13***	***SCF22***	***SCF31***	***SCF10***
ty, kg/m^3	55.86	52.84	44.82	47.25	52.24
ressive strength, (ksc	4.1, 4.0, 4.3	9, 3.3, 3.	6, 1.5, 1.	3, 2.6, 2.	1, 3.4, 3.
CVCM	0.812/0.0521	631/0.05	781/0.03	741/0.02	.852/.03
vation	Cracks	Cracks	cracks	No cracks	No cracks
T, W/m.K	0.034	0.036	0.035	0.038	0.034

Keywords:Amine polyol, water blown Rigid foam, Polyurethane Urea, No cracks

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Epoxy Resin-Based Skin Simulant Thermal Sensors

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Fire injuries constitute a major portion of industrial calamities, thereby rendering fire protective clothing an indispensable safety gear in several industries. Due to ethical and safety concerns, the performance of fire protective equipment cannot be tested on live subjects. Instead, thermal sensors are used to evaluate the efficacy of the gear by estimating the heat flux transmitted through the protective gear upon exposure to a heat source using a flame test mannikin. Among the various types of thermal sensors available, skin simulant sensors are specifically designed to simulate the heat transfer processes in human skin. Specifically, the sensing element of these sensors are chosen such that their thermal inertia, i.e., the product of thermal conductivity, specific heat and density, matches with that of human skin. While a variety of different materials have been used as the sensing element in skin simulant sensors, majority of them are based on polymers. In this study, the utility of epoxy resins as skin simulant thermal sensors has been explored. Using various techniques, the thermal constants of the material were evaluated. The thermal conductivity and density of the resin was found to be 0.24 W/mK and 1.1 g/cm^3 respectively. The thermal inertia of the resin was found to closely match that of human skin. Thermal sensors were fabricated out of the epoxy resin along with a K-type thermocouple embedded at or near the sensor surface. The performance of the sensor using a radiant heat source under different heat fluxes were also tested. The data obtained was used for burn injury prediction. The results were compared with that of a conventional copper calorimeter. The results suggest that epoxy resins can be a promising candidate for the fabrication of skin simulant thermal sensors and further improvements can be made by using suitable fillers in the resin matrix.

Keywords: Skin simulant thermal sensors, epoxy resin, burn injury prediction, thermal inertia

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Designing of poly(isocyanurate-urethane) crosslinked Auxetic materials Defense shielding, blast resistance, and lightweight structural applications

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**Indian Institute of Technology, Kanpur, Acknowledgment: DMSRDE (DRDO) Sponsor Project*

Scalable, lightweight, and mechanically robust auxetic materials represent a new generation of advanced structural materials with exceptional thermal stability, flexibility, and a negative Poisson's ratio (NPR). The presence of NPR is particularly significant, as it enables materials to expand laterally when stretched, enhancing energy absorption, and fracture toughness. This distinctive behavior allows superior impact resistance and recoverability, making them ideal for aerospace, defense, and protective systems. Moreover, their tunable architecture supports multifunctional performance, paving the way for smart and adaptive material technologies.

This study presents the fabrication of auxetic material (AM) and meta-auxetic materials (AAM) using poly(isocyanurate-urethane) (ITP) and Tetra ethylene Glycol (TEG) as crosslinkers. AAM were shaped in re-entrant molds to enhance auxetic performance through geometric design. The integration of flexible crosslinkers and re-entrant architecture not only improved structural resilience but also imparted excellent recoverability under repeated deformation cycles. AM achieved a Poisson's ratio of –0.43, while AAM reached a significantly enhanced value of –1.26 due to its auxetic architecture. Furthermore, the materials demonstrated remarkable dimensional stability and reversible deformation behavior even under dynamic loading conditions. These results indicate that the combination of tailored crosslinking, mold-directed geometry, and shape-memory effects enables the creation of highly tunable auxetic metamaterials (shown in Fig). The resulting materials exhibit an exceptional combination of negative Poisson's ratio, shape recovery, and mechanical robustness, making them highly suitable for impact-resistant, flexible, and energy-dissipating applications in advanced engineering and protective systems such as anti-mine shields, bomb-blast mitigation, vehicle blast protection, military helmets, and crash-resistant components in military aircraft.

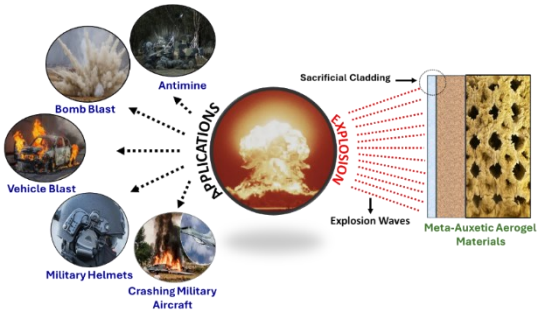


Figure. Schematic representation of explosive scenarios such as bomb blasts and anti-mine vehicle detonations (left) and the role of meta-auxetic aerogel materials (right) in absorbing shock and mitigating destructive impact when applied as protective barriers.

Keywords: Auxetic material, , Negative Poisson's ratio (NPR), meta-materials.

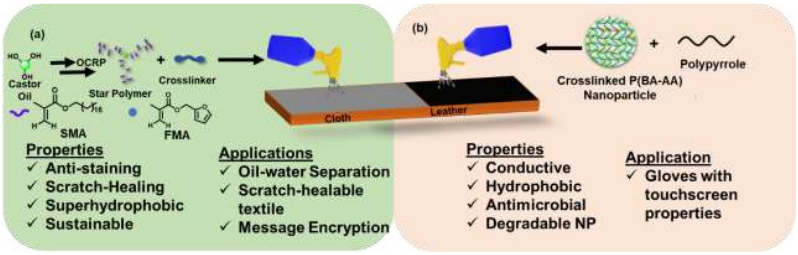
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Smart and Sustainable Polymer for Textile Coating *using* Organocatalyzed Controlled Radical Polymerization (OCRP) and Crosslinking

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Smart and sustainable polymer coatings offer significant potential for developing advanced textiles with properties such as superhydrophobicity, scratch-healing, conductivity, and antimicrobial activity. These coatings enhance functionality and durability while reducing environmental impact. In our work (**Figure 1a**), we designed a three-arm star copolymer via organocatalyzed controlled radical polymerization (OCRP), employing an organic small molecule catalyst and a castor-oil-based initiator, with stearyl methacrylate and furfuryl methacrylate as monomers.[1] The resulting copolymer was crosslinked with bis(3-ethyl-5-methyl-4-maleimidophenyl)methane (BIM) and applied as a coating on cellulose cloth to create a superhydrophobic and scratch-healable surface. The coated cellulose fabrics demonstrated excellent potential for oil–water separation and message encryption in anticounterfeiting applications. Moreover, the coatings exhibited thermo-responsive scratch-healing behaviour at 140 °C, anti-staining properties, and strong stability under diverse thermal, chemical, and mechanical conditions. In another study (**Figure 1b**), we synthesized a castor-oil-based crosslinker to prepare degradable crosslinked nanoparticles, which were used as dispersants for polypyrrole (PPy).When coated on leather, the material showed excellent thermal stability and demonstrated potential for fabricating touchscreen-compatible gloves, particularly suited for low-temperatureenvironments.[2]



Figures 1. (a) Preparation of superhydrophobic and scratch-healable fabric and (b) preparation of conductive,
hydrophobic, and antimicrobial leather for cold temperature gloves.

Keywords: controlled radical polymerization, nanoparticle, superhydrophobic, conductive, antimicrobial.

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Hybrid Nanoconjugates Derived by Polymer Functionalization

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Synthetic polymer-functionalized nanomaterials have recently emerged as a unique hybrid nanoconjugates with tailor-made opportunities and unique properties contributed from their polymeric as well as nanomaterial constituents. Here I will present our recent research development on synthesis of such polymeric nanoconjugates via functionalization of reversible addition-fragmentation chain-transfer (RAFT)-derived well-defined polymers on to the surface of highly advantageous nanomaterials such as protein-capped gold nanoclusters,1 or rare-earth metal-dopped nanocrystals.2 An effective approach of "grafting-to" method was adopted for the surface engineering of such nanomaterials to afford their core-shell structured nanoconjugates which displayed improved solution stability and stimuli-responsiveness. Such nanohybrids were characterized via various microscopic and spectroscopic studies, and were found to be fluorescent in nature to act as potential nanocomposites towards theranostic applications.

Keywords: *Nanomaterials, RAFT polymers, protein-polymer conjugates*

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Remarkable "Odd-Even Effect" in Supramolecular Polymerization and Piezoresponse of Naphthalene Diimide Derivatives

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Molecular engineering of π-conjugated systems is a powerful strategy to regulate their supramolecular polymerization, enabling precise control over electronic, morphological, and rheological properties. In a curiosity-driven project, we have recently investigated a series of structurally analogous naphthalene diimide (NDI)-based building blocks (Figure 1), in which the number of methylene units between the NDI core and the hydrogen-bonding amide functionality is systematically varied. Spectroscopic studies revealed cooperative supramolecular polymerization of all four NDI derivatives in hydrocarbon solvents, driven by hydrogen bonding and π–π stacking. Notably, UV-Vis and fluorescence spectroscopy indicated distinct internal order for these supramolecular polymers depending on odd or even spacers. Variable-temperature UV/Vis and DSC studies established that supramolecular polymers of the even-spacer systems (NDI-2 and NDI-4) display enhanced thermal stability, both in solid state and solution. Analysis of the cooling curves (constructed from UV/Vis studies as a function of temperature) using nucleation-elongation models reveals that the even-spacer systems possess significantly higher elongation temperatures (T_e) and cooperativity constants, indicating better cooperative supramolecular polymerization. Rheological experiments indicated much superior gelation for the NDI-2 even system compared to the NDI-1 odd system. Furthermore, piezo response force microscopy (PFM) measurements revealed an unprecedented odd-even effect in piezoelectric behaviour. While NDI-3 displayed a positive piezoelectric coefficient (d_{33} = +60 pm/V), NDI-2 (even) exhibited a negative value (d_{33} = –15 pm/V). Recent results from our group in this area will be discussed in this poster presentation.

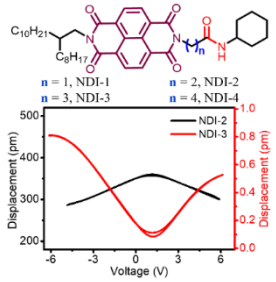


Figure 1. Molecular structures of NDI derivatives (top) and piezoelectric performances of NDI-2 and NDI-3 (bottom).

Keywords*:* Supramolecular polymerization, Napthalene diimide, Odd-even effect, Piezoelectric response

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Sealing & Transfer Solutions for Alternate Fuels

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GFL, India

The growing adoption of alternative fuels—such as ethanol-blended gasoline, biodiesel, Methanol, DME Hydrogen, and various synthetic low-carbon fuels—has created new challenges for sealing and fluid-transfer systems. These fuels often exhibit higher chemical reactivity, increased permeation tendencies, and broader operating temperature ranges compared to conventional petroleum-based fuels. As a result, traditional elastomeric materials frequently suffer from swelling, embrittlement, softening, or accelerated aging when exposed to these aggressive media. Fluoroelastomer have emerged as a highly reliable material class for sealing and transfer components in alternative-fuel environments due to their exceptional resistance to hydrocarbons, oxygenates, and chemically aggressive species. Their unique fluorinated polymer backbone imparts outstanding thermal stability, low fuel permeation, and long-term mechanical integrity. Advanced formulations—including peroxide-cured FKMs and specialty low-temperature or high-fluorine grades—further enhance compatibility with alcohol-rich fuels, biodiesel, and high-pressure gaseous fuels. This presentation outlines the performance advantages of fluoroelastomers in sealing applications, reviews material–fuel interaction mechanisms, and highlights key design considerations for hoses, gaskets, O-rings, and dynamic sealing elements used in next-generation fuel systems. The critical role of FKM in ensuring safety, reliability, and durability in alternative-fuel infrastructure is emphasized, supporting its continued use as a preferred material solution in the transition to cleaner energy technologies.

Dissipative self-assembly process in the space-time domain

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Inspired by the properties of living systems a strong interest exists in the development of life-like synthetic materials. The substrate-templated assembly of catalytic structures has recently emerged as an attractive process for the development of life-like synthetic systems, because it inherently connects catalysis and the formation of dissipative structures like microtubule formation. To understand macroscopic processes of living systems, we investigated dissipative self-assembly process in an agarose gel matrix. The gel matrix blocks mass transport through convection enabling an exploitation of the difference in diffusion rates between small and large structures to install and maintain concentration gradients that persist in time. We have recently shown that the local injection of surfactant **1** in an agarose hydrogel containing HPNPP results in the local formation of dissipative assemblies that persist in time with continuous diffusion of HPNPP to the assemblies and waste molecules diffusing away (Fig. 1A). The studies reveal an interdependence between the dissipative assemblies and the concentration gradients, and the possibility to activate dissipative processes with spatial control.[1]Furthermore, we have shown that by operating the ATP and HPNPP templated processes together in agarose gel matrix 1) catalytic hotspots spontaneously form upon the local activation of an ATP-templated self-assembly process, and 2) structures can indeed switch transiently from a thermodynamic to a dissipative state when a batch of chemical fuel is administered (Fig. 1B). Thermodynamically controlled self-assembly ensures long-time structural stability but also creates favorable conditions for the activation of an energy-dependent dissipative self-assembly.[2] The results show that the energy-dissipating process is more efficient when thermodynamically stable assemblies are present in the system.

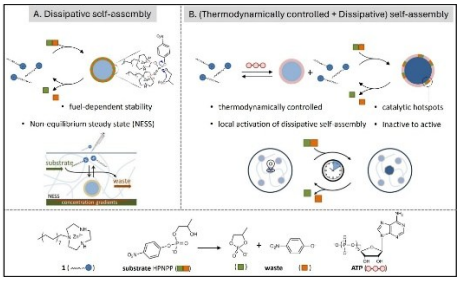


Figure 1 – A. Schematic representation of the chemical processes that occur in a gel containing HPNPP upon the injection of **1**. B. Schematic representation of the chemical processes that occur in a gel containing **1** and ATP upon the injection of HPNPP.

Keywords: self-assembly processes, hydrogel matrix, space-time domain, spatial programmability, dissipative self-assembly, adaptive materials.

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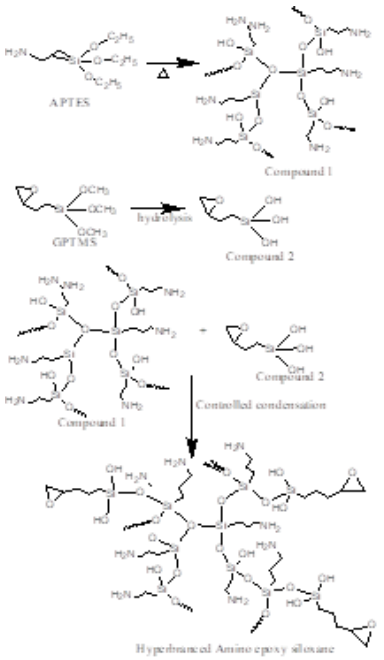
Inherently Conducting and Flame-Retardant Silicone-Epoxy Co-Polymer: Synthesis, Characterization and Coating Performance

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In recent years, the development of advanced multifunctional polymeric materials that combine thermal stability, flame retardancy, electrical conductivity, and chemical resistance has become increasingly important for high-performance coatings in aerospace, marine, electronics, and construction applications. This study presents the synthesis, characterization, and application of an inherently conducting, flame-retardant silicone epoxy co-polymer, engineered via the controlled sol-gel condensation of three organosilane precursors—3-aminopropyltriethoxysilane (APTES), Diethoxydimethylsilane(DMDES) and 3-glycedyloxypropyltrimethoxysilane (GPTMS). The primary aim was to develop a hybrid inorganic-organic co-polymer system that merges the electrical conductivity of functional amine-epoxy networks with the thermal stability and flame-retardant properties of a siloxane-based backbone, enabling its use as a high-performance protective coating material.

The synthesis of the co-polymer was achieved via a stepwise sol-gel route under controlled pH and temperature conditions to regulate hydrolysis and condensation reactions. Initially, GPTMS and DEDMS underwent hydrolysis of its methoxy groups to form reactive silanol groups, which subsequently condensed with the ethoxy-derived silanols of APTES. Simultaneously, the primary amine group in APTES reacts with the epoxide ring in GPTMS via nucleophilic ring-opening, forming a cross-linked siloxane-epoxy hybrid network. The synthesized silicone epoxy co-polymer was characterized using FTIR, NMR, TGA, DSC, SEM and X-ray diffraction (XRD).



To impart mechanical strength, the synthesised co-polymer matrix was reinforced with fillers such as calcium Aluminium silicate, antimony trioxide and tricresyl phosphte. The resulting material exhibited surface conductivity in the range of 10^{-9} to 10^{-4}S/cm, suitable for electrostatic discharge (ESD) protection and antistatic coatings. Flame retardancy was evaluated via limiting oxygen index (LOI) and vertical burning (UL-94) all of which indicated superior flame resistance compared to conventional epoxy systems. The material achieved a UL-94 V-0 rating. In conclusion, this study introduces a novel inherently conductive and flame-retardant silicone epoxy co-polymer synthesized via a controllable sol-gel approach using APTES, DMDES and GPTMS precursors. Its unique combination of electrical, thermal, and mechanical properties makes it highly suitable for multifunctional protective coatings in demanding industrial environments. This work not only advances the field of hybrid polymeric coatings but also opens pathways for future exploration in smart materials and energy-related applications.

Key words: Silicone epoxy Co-polymer, Electrical conductivity, Flame retardancy.

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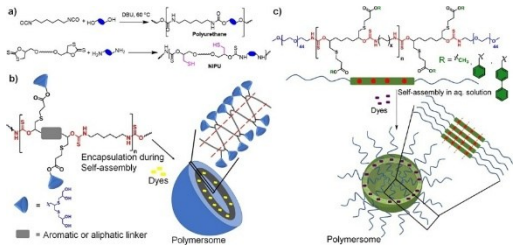
***Corresponding author:** smithanimesh100@gmail.com

Synthesis and Self-assembly of Amphiphilic Polythiourethanes: Effect of Backbone Hydrophobicity on Dye Loading and Stability

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Polyurethanes (PUs) are traditionally synthesized by the polyaddition of diols with diisocyanates in the presence of a catalyst. It is challenging to get rid of phosgene which is used for the preparation of diisocyanates. Due to such toxicity and reactivity of isocyanates to moisture, greener approaches were developed to synthesize PUs.[1] In this regard polythiourethanes (PTUs) have emerged as an alternative for their ease of synthesis, and H-bonding functionality along the chain. Moreover, during polymerization, each addition of amines generates free thiols that could further be utilized to couple hydrophobic groups, drugs or crosslinking of the hydrophobic membrane to increase the stability of the formed nano-aggregates.[2] In this study, the one-pot synthesis and self-assembly of several polyethylene glycol and oligoglycerol-based amphiphilic PTU will be discussed (Figure 1).[3, 4] The aromatic linker and pendant containing polymers had higher encapsulation ability than the other aliphatic linker containing polymers. Further we unravelled the mechanism of dye exchange using FRET.



Figures 1. a) Synthesis of polyurethane and polythiourethanes (PTU); b) and c) Schematic description of polymersome formation and dye encapsulation in water by PTU based amphiphilic polymers.

Keywords: Polythiourethane, Oligoglycerol dendron, Fluorescence resonance energy transfer (FRET), Polymersomes, Polyethyleneglycol (PEG).

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Exploring Innovative Polyurethane Nanocomposites via Dynamic Disulfide Bond Engineering and Eri Silk Reinforcement

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Polyurethane (PU) is a versatile step-growth polymer characterized by microphase-separated hard and soft domains. Hard segments, derived from isocyanates and chain extenders, impart rigidity and strength, while soft segments from polyols confer elasticity and flexibility. Incorporation of disulfide-based chain extenders introduces dynamic covalent bonding, enabling reversible bond exchange, enhanced stretchability, and adaptive mechanical response. We explored blending disulfide-functionalized PU with Eri silk to produce composite fibers flexible at low temperature climatic conditions, such as Siachin and north Kashmir. PU durability and processability synergize with the thermal insulation and moisture-wicking properties of Eri silk, yielding fibers that retain flexibility and mechanical integrity under ultra low temperature conditions. Polyurethane matrices engineered with dynamic disulfide bonds and graphene nanoplatelets exhibit exceptional potential for flexible strain sensors. These synthesized nanocomposites exhibited high stretchability, piezo resistive sensitivity, electrical conductivity, and autonomous self-healing. These flexible sensors enabled to detect human motion efficiently. Furthermore, we also explored PU functionalized with MXene/SWCNT buckypaper for thermoelectric property. MXene/SWCNT/PU free-standing films were fabricated via vacuum assisted filtration and co-solvent processing. Thermoelectric module comprising p-type MXene/SWCNT/PU nanocomposites integrated with nickel wire arrays, exhibited improved Seebeck coefficients, from 175 to 200 μV/K, highlighting the synergistic effects of nanoparticle stabilization and optimized architecture. Overall, disulfide-functionalized PU provides a versatile platform for advanced material technologies, spanning low temperature fiber composites, highly stretchable strain sensors, and flexible thermoelectric devices. Its dynamic covalent chemistry imparts mechanical robustness, thermal stability, and self-healing capacity, positioning PU as a pivotal material system for next-generation polymeric applications.

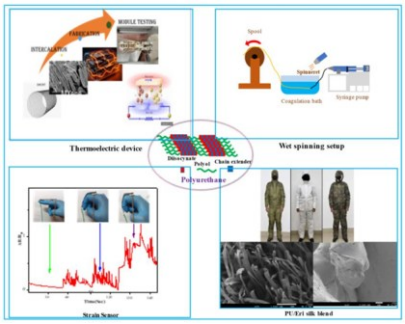


Figure 1 Dynamic Disulfide Bond-Driven Polyurethane Nanocomposites application

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Development of Porous Conductive Polymer Composites for Flexible and Wearable Tactile Sensors

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The growing demand for flexible and wearable electronics has driven the development of advanced tactile sensing materials capable of accurate and reliable force detection [1]. In response to this need, this study focuses on the development of porous conductive polymer composites by integrating carbon black (CCB) into a polydimethylsiloxane (PDMS) matrix (Figure A&B), aiming to enhance the piezoresistive properties critical for tactile sensing applications. The introduction of controlled porosity significantly improves the compressibility and sensitivity of the composite under mechanical stimuli, which is essential for detecting subtle pressure variations in wearable devices [2]. Comprehensive characterization including morphological, electrical, and mechanical analyses confirms that the porous PDMS/CCB composite exhibits high flexibility, repeatability, and responsiveness to tactile inputs. As shown in Figure C, the sensitivity of the porous samples increases with rising pressure, demonstrating a clear positive correlation between applied force and sensor response. This indicates that the porous structure enables more effective deformation under pressure, enhancing the contact and tunnelling effects within the conductive CCB network, which leads to measurable and consistent resistance changes [3]. Additionally, the porous composite maintains excellent stability over 100 compressive loading cycles, highlighting its durability and suitability for long-term use in wearable tactile sensors (Figure D). These results demonstrate the promising potential of the porous PDMS/CCB composite as a cost-effective and scalable solution for emerging applications such as electronic skins, wearable health monitors, and human–machine interface systems.

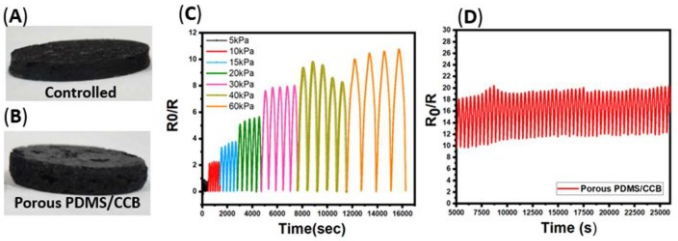


Figure: (A) Controlled and Porous PDMS/CCB Samples (B) R0/R of the porous PDMS/CCB composite under cyclic loading at different pressures (D) R0/R response of the porous PDMS/CCB composite under 100 compression cycles.

Keywords: PDMS (Polydimethylsiloxane), Conducting Carbon Black (CCB), piezoresistivity, tactile sensing.

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Superior Corrosion Resistance and Spot-Weldable Polymer Coating For Mild Steel

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In this work, we synthesized conducting polyaniline emeraldine salt (PANI-ES), which was subsequently used for the in-situ synthesis of a spot-weldable polyamic acid–PANI-ES (PAA–PANI-ES) composite coating. The PAA–PANI-ES coating was applied to mild steel using an automatic bar coater, which, upon drying, formed a uniform polyimide–PANI-ES (PI–PANI-ES) coating with a thickness of 10 ± 2 µm. The PI–PANI-ES-coated steel substrates were spot-weldable, whereas substrates coated with pure PI were not spot-weldable. We achieved superior corrosion resistance on mild steel substrates (>500 h, 5% red rust) using the PI–PANI-ES coating, compared to ~120 h (5% red rust) for the pure PI coating. Both pure PI and PI–PANI-ES coating systems exhibited excellent adhesion to the mild steel substrate and successfully passed the required forming tests. Additionally, both types of coatings showed strong adhesion to polyester-based powder paint. The incorporation of conducting PANI-ES powder into the PI matrix enhanced the corrosion resistance and AC conductivity of the coating system.

Keywords: Polyimide, Polyaniline Emeraldine salt, Corrosion, Spot-weldable, Mild steel

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SPARC LECTURE

Polymers and CO_2: a marriage made in heaven!

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Abstract: Our society currently demands a sustainable strategy when making allowances for all products we use in or daily life. Polymeric products, either in the form of thermoplastics or thermosets, do not make any exception. However the term sustainability, when focusing on polymeric products, usually encompasses a large variety of possible interpretations ranging from a sustainable production process up to the a sustainable (e.g. circular) end-of-life strategy. Supercritical CO_2 is widely considered a green solvent and its usage in combination with polymers has been attracting great interest both at academic and industrial level during the last 3 decades [1]. Such a wide interest stems from a variety of reasons. On one hand, $scCO_2$ technology has become cheaper and better understood over the years. On the other hand, its applicability in the polymer world encompasses a variety of different roles and functions. Indeed, $scCO_2$ can be used as a polymerization medium (e.g. for polycarbonates [2]), extracting solvent for the removal of impurities (e.g. in combination with mechanical recycling [3]) as well as processing aid during extrusion (e.g. for foam production [4]).

In this work we will start by providing a quick overview of the properties of $scCO_2$ as well as of the related technologies. After quickly touching upon the use as polymerization medium, we will then explore in depth applications as extracting solvent for the removal of impurities and unreacted monomer. Finally we will focus on extrusion processes and showcase the use of $scCO_2$ for foam production and poly(vinyl chloride) (PVC) recycling.

Keywords: polymers, supercritical CO_2, foaming, extraction, processing aid.

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Sustainable Catalyst-Free Covalent Adaptable Networks

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Abstract: Recycling of crosslinked thermosets remains a major challenge because their permanent network structures prevent reprocessing and lead to persistent waste. Covalent adaptable networks, or vitrimers, have emerged as an exciting solution, enabling recyclability through dynamic bond-exchange reactions while maintaining the strength and durability of conventional thermosets. However, most existing systems still depend on external catalysts, which can leach out and raise environmental concerns.

In our work, we explored complementary routes toward sustainable, catalyst-free CANs. One approach introduces internal carboxylic acid groups directly into the polymer architecture—using star-shaped poly(lactide-co-glycolide) crosslinked with pyromellitic dianhydride—to trigger transesterification without any added catalyst. These biodegradable networks achieved high gel contents above 95%, stiffness comparable to poly(L-lactide) around 1.6 GPa, and retained their mechanical integrity fully after recycling. They also degraded rapidly under composting conditions, reaching more than 60% mass loss within 25 days and nearly 90% after 60 days, while showing additional functionalities such as shape-memory and reusable adhesion. A complementary design incorporated intrinsic catalytic activity into the network backbone itself by polymerizing a self-synthesized tertiary amine–diol monomer through polyaddition. The resulting vitrimers exhibited dense crosslinking (97% gel content), robust mechanics with a Young's modulus of about 555 MPa, and excellent recyclability, maintaining over 80% of their modulus after two cycles. Their dynamic behavior followed an Arrhenius relationship, with a topology-freezing temperature near 89 °C and an activation energy of 189 kJ mol^{-1}.

Together, these materials demonstrate how catalyst-free CANs can unite recyclability, mechanical performance, and, in the case of degradable backbones, environmental compatibility. They point toward a broader vision of sustainable thermosets that combine high performance with circularity and ecological safety.

Keywords: vitrimer, recyclability, plastic pollution

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Functional Elastomers & Smart Rubbers at IPF Dresden: From Dielectric Actuators to Interactive Fiber-Rubber Composites and Triboelectric Generators

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Emerging technologies – such as soft robotics, medical & health care applications, sustainable energy harvesting – are enabled by functional devices. These are often based on composites that resemble a combination of different materials – soft & more rigid polymers, functional & reinforcing textiles, metallic shape memory alloys etc. - with intrinsic properties enabling for different functionalities within the device or system. Beside the "classical" entropy elastic mechanical behavior of elastomers, that should allow for reversible large deformations at low forces, the implementation of defined electrical and/or thermal conductivity [1, 2], magnetosensitivity/magnetostriction, dielectric properties [3] etc. is of utmost importance the realize such elastomer based functional devices. This includes also the adaption of processing & curing properties for example of liquid diene rubbers [4, 5] to allow for conventional & unconventional device forming & manufacturing techniques. The lecture will cover some approaches and examples that have been followed in this research at IPF Dresden in the past years.

Keywords: Functional Elastomer, Dielectric Elastomer Actuator, Interactive Fiber-Rubber Composites

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Biological properties of highly branched poly(N-*iso*propyl acrylamides)

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Highly branched poly(N-isopropyl acrylamide) (HB-PNIPAM) has been established by us as an active component of biomaterials that respond to binding to bacteria[1,2], fungi[3] or human cells[4]. This binding triggers a desolvation of segments located close to the chain ends. Here we describe how these polymers can disrupt biofilms and we discuss their general biocompatibility. HB-PNIPAM is synthesised by a self-condensing radical polymerization by copolymerisation of NIPAM with monomers such as **1**. Monomers such as **1** place the dithioate functionality at the chain ends and this allows for facile modification of the chain ends. In this paper we discuss how these polymers can be used to disrupt biofilms and we will discuss their biocompatability.

HB-PNIPAM with vancomycin end groups were shown by us to reduce biofilm formation by the Gram-positive species, *Staphylococcus aureus*.[5] This effect is due to binding of vancomycin end groups to the Ala-Ala target in the cell wall of Gram-positive species. We have recently shown that Gram-negative (*Escherichia coli*) biofilms can also be disrupted by HB-PNIPAM with polymyxin end groups. These polymers disrupt biofilms by binding to lipopolysaccharide present in the cell membrane.

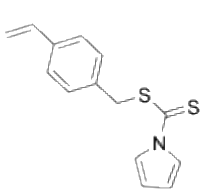


Figure 1 A branching monomer used in self-condensing copolymerization of NIPAM

However, we will also describe unexpected results on the disruption of *E.coli* biofilms using HB-PNIPAM with pyrrole end groups, as produced from copolymerization with **1**. At the current time there appears to be no obvious binding target for such polymers but we will also present data showing that equivalent carboxylic acid functional polymers do not disrupt biofilms.Biocompatibility of these polymers requires multiple studies and here we will present our work on the release of inflammatory cytokines (IL1β, IL6 and TNFα) from activated monocytes (macrophages) and the production of reactive oxygen species in the presence of various HB-PNIPAMs.

Keywords: Poly(N-*iso*propyl acrylamide), bacteria, biofilm, biocompatability

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POSTERS

Design and synthesis of fluorene-functionalized phenoxy-imine ligated titanium and zirconium complexes as post-metallocene olefin polymerization catalysts

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The development of transition metal-catalyzed olefin polymerization has revolutionized the polyolefin industry, enabling unprecedented control over polymer microstructure. The evolution from heterogeneous Ziegler-Natta catalysts to well-defined single-site metallocene systems has highlighted how ligand innovation redefines the boundaries of olefin polymerization catalysis. Among various ligand classes, Schiff-base derivatives, particularly phenoxy-imine (FI) ligands have emerged as powerful frameworks due to their facile synthesis, modularity and ability to stabilize diverse metal centers. Building on Fujita's ligand-oriented design principles,[1] we synthesized a set of fluorene-derived FI based Ti(IV) and Zr(IV) complexes to explore the structural modulation of ligand architecture on olefin polymerization behavior. Deprotonation of FI ligands with ^{n}BuLi followed by metalation with $ZrCl_4.2THF$ afforded bis-phenoxy imine Zr(IV) complexes, achieving high ethylene polymerization activities (up to 225.6 kg PE·mol^{-1} h^{-1} at 40 °C, 1 atm) with trityl borate/trialkylaluminum. In contrast, similar reaction with $TiCl_4$ unexpectedly yielded a novel bifluorene-bridged Ti(IV) complex via *in situ* coupling between two fluorene moieties.[2] Interestingly, SCXRD of this complex revealed that the bridged ligand enforces a *trans* orientation of the chloride ligands, deviating from the *cis* arrangement typically associated with high activity.[3] Thereby, resulting in lower polymerization efficiency compared to non-bridged analogues which were prepared *via* direct HCl-elimination reactions. Polymerization studies further reveal that, that titanium catalysts favor narrow monomodal molecular weight distributions at low temperatures, whereas both titanium and zirconium systems yield well-defined multimodal polymers under broader reaction conditions. These results reveal that subtle structural difference around the metal center can dramatically reshape the catalytic performance. This work expands the structural diversity of FI-type catalysts and highlights its potential in engineering next-generation catalysts for precise polyolefin synthesis.

Keywords: Titanium, C–C coupling, Post-metallocene, FI catalyst, Ethylene polymerization.

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Insights into the Photocatalytic Degradation and Structural Evolution of PET Nanoplastics Mediated by Hematite Nanoparticles

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Plastic pollution constitutes a critical global environmental and human health concern due to the high durability and resilience of synthetic polymers. As commercially available nanoplastics remain prohibitively expensive, this study focuses on the in-situ synthesis of polymer nanoplastics to investigate their physicochemical properties, photocatalytic degradation behavior, and biological implications[1]. Photocatalytic degradation was performed in an annular photoreactor employing hematite (α-Fe_2O_3) nanoparticles with an average size of ~200 nm as a visible-light-active catalyst[2]. The extent and efficiency of polymer degradation were systematically evaluated using high-performance liquid chromatography (HPLC) and mass spectrometry (MS), enabling detailed quantification and identification of degradation intermediates. Structural and morphological changes during degradation were further characterized via Dynamic light scattering (DLS) and small-angle X-ray scattering (SAXS), providing insights into polymer chain scission and aggregation dynamics. Complementary *in vitro* cytotoxicity assays were conducted to assess the cellular response to both pristine nanoplastics and their photocatalytically degraded byproducts. The integrated results reveal that hematite-mediated photocatalysis facilitates substantial polymer degradation under visible irradiation. This study enhances the existing knowledge of nanoplastic degradation mechanisms by coupling photocatalytic performance with molecular-level degradation analysis and toxicological evaluation, contributing to the development of sustainable plastic remediation strategies.

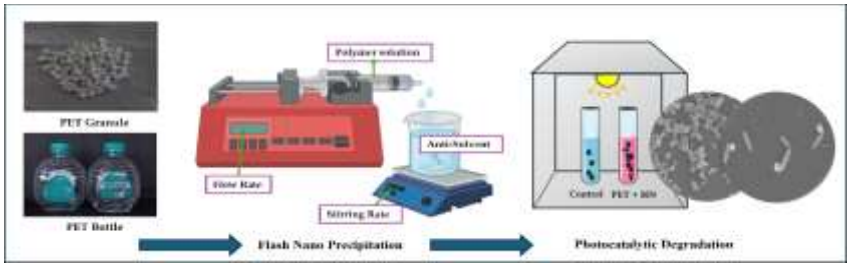


Figure 1 – Schematic of PET nanoparticle synthesis via Flash Nanoprecipitation and photocatalytic degradation using hematite nano-ellipsoids.

Keywords: Nanoplastics, Hematite, Flash nano precipitation, Photocatalytic degradation.

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Terpene-based Random and Block copolymer by PET RAFT polymerization: Reactivity and Thermal properties

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Terpene-based acrylic monomers offer a sustainable alternative to traditional acrylics. Their variety allows for tuning properties to match or even exceed those of petrochemical monomers.[1] Polymerization of a bio-based monomer, viz. nopyl methacrylate, unexplored for controlled radical/living polymerization, was studied using photoinduced electron transfer–reversible addition–fragmentation chain transfer (PET-RAFT) polymerization under visible light (λmax = 485 nm). PET-RAFT polymerization is versatile, oxygen-tolerant, energy-efficient, and compatible with a wide range of monomers, making it highly sustainable.[2] In this study, several commonly used chain transfer agents and photocatalysts are screened with nopyl methacrylate, and its reactivity with 4-Cyano-4 [(dodecylsulfanylthiocarbonyl)sulfanyl] pentanoic acid (CDTPA) as a chain transfer agent and Eosin-Y as a photocatalyst in THF as a solvent is investigated. Kinetics studies showed the controlled nature of polymerization, and a high molecular weight polymer of narrow dispersity was obtained. Further, block and random copolymers of nopyl methacrylate with commonly used non-functional methacrylates such as lauryl acrylate, methyl methacrylate, hexyl methacrylate, and functional methacrylates such as hydroxyethyl methacrylate, furfuryl methacrylate, and glycidyl methacrylate of narrow dispersity were synthesized. The adhesion properties of the block and random copolymers were also examined.

Keywords: Terpene, Biobased, PET-RAFT, Adhesion Study.

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Dynamic Triblock Copolymer Design for Self-Healing and Redox-Active Superhydrophobic Surfaces

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The development of robust self-healable superhydrophobic surfaces remains a significant challenge due to the simultaneous requirement of restoring both low surface energy and hierarchical surface roughness. In this work, we propose a facile strategy to achieve such multifunctionality within a single polymer matrix by exploiting a ferrocene- and fluorine-containing triblock copolymer. Herein, in this case, a triblock copolymer incorporating ferrocene and fluorine unit was synthesized via RAFT-mediated polymerization-induced self-assembly (PISA).[1] The copolymer displays dual self-healing through dynamic covalent Diels–Alder/retro-Diels–Alder reactions and reversible host–guest complexation. By creating dual-scaled micro/nanostructures that can provide long-lasting water repellency, the design makes it possibly to create porous multicompartment micellar morphologies.[2] Simultaneously, reversible host-guest complexation between ferrocene and β-cyclodextrin and synergistic dynamic covalent Diels-Alder/retro-Diels-Alder chemistry are used to incorporate the ability to cure oneself.[3,4] Addition of ferrocene moiety can provide redox-responsiveness, enabling external switching of interfacial characteristics. When combined, this system envisages a highly adaptable hydrophobic coating platform by combining macro-to-nanoscale phase segregation, autonomous repair, and variable redox activity. This multifunctional system unites redox activity, hydrophobicity, autonomous repair, and hierarchical nanostructure, presenting a promising platform for next-generation smart coatings.

Keywords: Dynamic covalent Diels–Alder chemistry, Hierarchical micro/nanostructures, Redox-responsive coatings, Self-healing Phenomenon.

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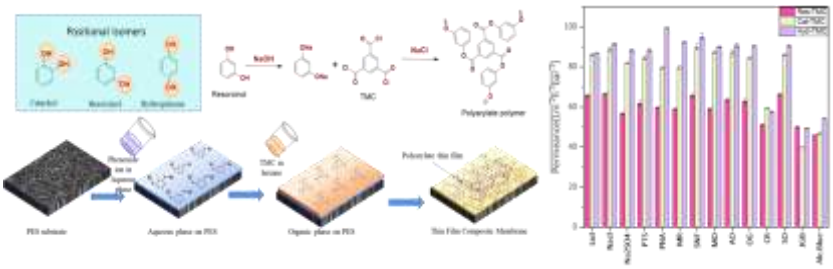
Positional Isomerism driven microstructural tuning in polymeric membranes for enhanced dye desalination

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Polymeric membranes have emerged as a sustainable platform for molecular separations, offering superior energy efficiency, scalability, and environmental compatibility compared to conventional purification methods.[1] Addressing the challenge of dye-laden wastewater,[2,3] this study presents a series of microporous polyester membranes fabricated via interfacial polymerization[4] of dihydroxybenzene isomers (catechol, resorcinol, and hydroquinone) with trimesoyl chloride on polyethersulfone supports. The positional isomerism of the monomers significantly influenced the membrane microstructure, hydrophilicity, and separation performance. The hydroxyl-rich aromatic frameworks provided rigidity, hydrogen bonding capability, and enhanced water transport, while maintaining high rejection efficiency. The optimized membranes achieved >98% dye rejection and <10% salt passage during dye-salt separation tests, highlighting the potential of tunable polymeric architectures for efficient wastewater purification and resource recovery. This work underscores the importance of molecular-level design in polymeric membrane chemistry to achieve precise control over permeability-selectivity trade-offs for next-generation sustainable separations.



Keywords: Positional Isomers, Interfacial Polymerization, Mircoporosity, Efficient Separation, Nanofiltration.

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Force-controlled capture and release of small molecules with covalent organic cages

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The mechanochemical release of small molecules holds significant potential for the advancement of many controlled release applications in medicine and materials science, e.g., drug delivery,[1] self-healing material,[2] etc. Various mechanophore (force-sensitive molecule) designs have been used for the release of small molecules.[3] Despite these advancements, the systems described are limited in the diversity and/or quantity of molecules they can release per stretching event because the cargo molecule must be covalently attached to/as the mechanophore. The ability to store and release cargo molecules not covalently bound to the polymer should enhance the diversity of cargo molecules and increase the efficiency of release. Here, we use mechanical force to actively deform the structure of a molecular cage to facilitate the capture and release of cargo molecule within its cavity.

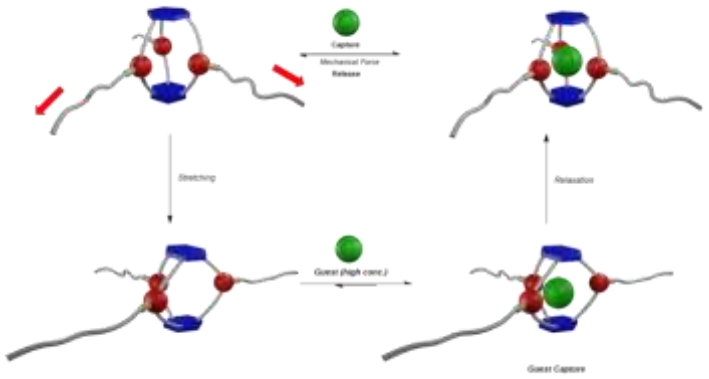


Figure 1 – Capture and Release of cargo molecules using organic cage polymer

Keywords: Mechanochemistry, Covalent cages.

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Fluorine-free Superhydrophobic Polyacrylate Coating via Controlled Radical Polymerization for Multifunctional Application

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Superhydrophobic coating materials show great promise for separating oily pollutants and anti- staining and water-repellent textile preparation. However, most of the acrylate superhydrophobic coatings are prepared using fluorine-based monomers. Hence, we have reported the development of a superhydrophobic and self-healing coating without fluorine monomer. We have reported the synthesis of a three-arm initiator ($COBr_3$) from castor oil (CO) and its use in organocatalyzed controlled radical polymerization, namely, reversible complexation-mediated polymerization (RCMP).[1] Unlike other living radical polymerization techniques, RCMP does not require any metal catalyst or sulfur-containing agents. A range of petroleum- and bio-based monomers were employed to synthesize star-architecture homo- and co-polymers with moderate to high monomer conversions (52–89%) and low dispersity (1.15–1.49). Specifically, star-P(SMA_{45}-*r*-FMA_{22}) and star- P(SMA_{50}-*r*-FMA_7) were synthesized and crosslinked using bis(3-ethyl-5-methyl-4-maleimidophenyl) methane (BIM) through the Diels–Alder reaction. These polymers were coated on cellulosic substrates such as cotton cloth (CC), where SMA and FMA refer to stearyl methacrylate and furfuryl methacrylate, respectively. The coated CC demonstrated a water contact angle (WCA) of >150° and sliding at 10°, indicating superhydrophobicity. These coated CCs exhibited significant potential for oil–water separation and message encryption in anti-counterfeiting applications.[2] Additionally, the coatings exhibit thermo-responsive scratch- healing behavior at 140 °C and possess anti-staining capabilities. These water-resistant and breathable fabrics also maintain stability across a wide range of temperatures, chemical environments, and under abrasion. This smart, sustainable, and multifunctional textile platform holds promise for diverse industries spanning from oil remediation to functional textiles.[3]



Figure 1. A concise overview of the work reported.

Keywords: Superhydrophobic, self-healing, Diels-Alder reaction, thermo-responsive, anticounterfeiting.

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PET-RAFT Polymerization Enabled by Squaraine Dyes and Alkylaminoethyl Methacrylate

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PET-RAFT polymerization using visible light enables controlled synthesis under mild, ambient conditions, offering advantages such as temporal control, green chemistry compatibility, and improved scalability. [1] Organic photoredox catalysts (PCs) based on squaraine dyes were synthesized and investigated for PET-RAFT polymerization under visible light irradiation (λ_{max} = 485 nm). The addition of triethylamine (TEA) suppresses self-aggregation of squaraine dye apart from being oxygen quencher [2] and sacrificial electron donor [3], thereby accelerating the polymerization and eliminating the induction period often observed with other PCs. This system provided efficient polymerization of methyl methacrylate and a broad range of functional methacrylates, achieving good control over molecular weight and narrow dispersity. Importantly, the process works under mild conditions, with temporal control through light "ON–OFF" switching and without the need for an inert atmosphere, highlighting its robustness. Mechanistic studies demonstrate that the pathway shifts between oxidative and reductive electron transfer depending on the presence of TEA. Synthesis of block and random copolymers, as well as polymerization in continuous-flow and aqueous media, was demonstrated showcasing versatility of squaraine dye PCs in PET-RAFT technique. [4] Building on the role of TEA, we designed and synthesized alkylamino-containing methacrylate monomers as intrinsic replacements for TEA. These monomers exhibited multifunctional behavior similar to TEA. Notably, their PET-RAFT polymerization in both batch and continuous-flow did not compromise the control over polymerization. Effect of the nature of alkylamino group – tertiary, secondary or primary and the structure of alkyl group was shown to influence the efficiency of suppression of aggregation, electron donor and oxygen quenching. Incorporation of alkylamino group into monomer also affords pH-responsive polymers. Amphiphilic block copolymers were synthesized and self-assembly in aqueous solution was studied.

Keywords: PET-RAFT polymerization, Squaraine dye, suppressed self-aggregation, Continuous Flow, and Aqueous Media.

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Synthesis and characterization of a conducting copolymer via electropolymerization for electrode in energy storage applications

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To fulfill the energy demand, there is a quest for alternative energy storage technologies that would lead to using cleaner, more durable, eco-friendly, sustainable, and efficient energy storage technologies and innovative systems. The continuous development and demand in power supply systems require versatile energy storage devices offering a wide range of energy density and power density [1]. Electrode development is currently the focus of researchers around the world. Therefore, we aim to synthesize a novel flexible electrode material with improved electrochemical properties and a wide range of energy density and power density. We have decided to synthesize a thiophene-based alternating copolymer via the electropolymerization technique. Electropolymerization is a versatile electrochemical technique employed to synthesize conducting and functional polymer films directly onto electrode surfaces. The process involves the oxidation or reduction of monomer units at an electrode, generating reactive intermediates such as radical cations or anions, which subsequently couple to form polymer chains. Unlike conventional chemical polymerization methods, electropolymerization provides precise control over film thickness, morphology, and composition by tuning electrochemical parameters such as potential, current density, scan rate, and electrolyte environment. The method also enables in-situ doping, resulting in polymers with tailored electrical, optical, and mechanical properties. Electropolymerized films exhibit strong adhesion to substrates and can be fabricated in a range of nanostructures, making them attractive for applications in energy storage devices, electrochromic systems, etc [2]. Firstly, we modified thiophene with Isopropoxyboronic acid pinacol, followed by its Suzuki coupling reaction with dibromohydroquinone to form a trimer with 2 units of thiophene and 1 unit of dibromohydroquinone. Further, this trimer was electropolymerized in a 3-electrode system with a 1.0 cm^2 area of ITO-coated glass as working electrode, silver mesh as counter electrode, Ag/AgCl/3M KCl as reference electrode, and 0.1M tetrabutylammonium hexafluorophosphate in acetonitrile as supporting electrolyte. A definite concentration of monomer was added to the electrolyte, and cyclic voltammetry in the potential window 0 to 2.0V was performed for numerous cycles at a scan rate of 50 mV/s [3][4]. Electropolymerized ITO glass was washed with acetonitrile to remove adsorbed monomer for further electrochemical analysis, such as EIS, CV, and GCD, to determine its specific capacitance and cyclic stability for its application as an electrode in energy storage devices.

Keywords: Polythiophene, electro polymerization, energy storage, cyclic voltammetry.

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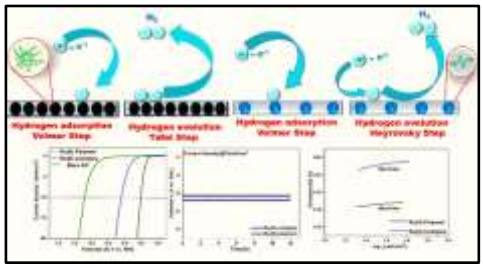
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Synthesis of Asymmetric Multidentate Azo-Based Redox-Active Ligand and Its Coordination Compounds with Ruthenium (II) for the Development of Efficient Electrocatalysts for Enhanced Hydrogen Evolution Reaction

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Enhancing the effectiveness and accessibility of water-splitting devices through electrocatalysis is essential for promoting the use of green hydrogen as an eco-friendly fuel. This research focuses on the strategic design of efficient Ru-based electrocatalysts for hydrogen evolution reactions (HER). An asymmetric azo ligand was synthesized and used to prepare two Ru(II) compounds by varying the metal-to-ligand ratio, all exhibiting reversible electrochemical properties essential for electrocatalyst development. The electrocatalytic performance of the Ru(II) Complex and Ru(II) Polymer for HER was evaluated using linear sweep voltammetry (LSV), potentiodynamic polarization, electrochemical impedance spectroscopy (EIS), and chronopotentiometry in a 0.5M aqueous H2SO4 solution. It is possible to vary the metal: ligand ratio to produce a Ru(II) Complex (L: M::1:0.5), where a single Ru(II) centre is coordinated to two ligands and a Ru(II) Polymer (L: M::1:3), where ditopic ligand is working as a bridge between 2/3 different Ru(II) metal centres. This synthetic route was chosen to investigate the influence of bridging ligands and alterations in the coordination sphere surrounding the central metal ion, as well as the impact of higher concentrations of the metal center on electrocatalytic performance, as the metal centers serve as active sites for the transfer of electrons to H^+ ions in an acidic medium. The Ru(II) Polymer, with more metal centers than the Ru(II) Complex, showed a lower onset potential (-0.162 V vs. -0.340 V), lower overpotential at 10 mA/cm² (-0.202 V vs. -0.435 V), and a smaller Tafel slope (60 vs. 96 mV/dec), showing easier electron transport and a different HER mechanism. EIS experiments show that the Ru(II) Polymer has a lower HER charge transfer resistance than the Ru(II) Complex.



Keywords: Hydrogen Evolution Reaction, Azo ligand, Ruthenium (II) Complex and Polymer, Electrocatalyst, Hydrogen Energy, Low Overpotential.

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A Naphthalimide-Based Macromolecular Fluorimetric Probe for Selective Formaldehyde Detection and pc-LED Integration

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Formaldehyde (FA) is a highly toxic, carcinogenic compound widely utilized in industrial manufacturing, polymer production, and preservation processes.[1] Its broad presence in environmental, food, and biomedical systems underscores the urgent need for reliable, selective, and highly sensitive detection strategies to ensure safety, regulatory compliance, and effective risk management.[2] Polymeric sensors, particularly water-soluble fluorescent systems with pendant amine groups, overcome limitations of small molecules by offering enhanced sensitivity, tunable functionality, and eco-friendly operation.[3] Their structural versatility ensures stability, selectivity, and cost-effectiveness, making them highly promising for biological and environmental formaldehyde detection.[4,5] Herein, we report the development of a water-soluble, naphthalimide-based fluorescent polymeric probe, DCP5, capable of rapid and selective FA sensing under physiological pH conditions. The polymer incorporates aromatic amine functionalities within its side chains, which undergo a specific addition–elimination reaction with FA to generate a stable imine. This transformation suppresses the intrinsic photoinduced electron transfer (PET) process, resulting in a pronounced "turn-on" fluorescence response in aqueous media. The imine formation was confirmed by electrospray ionization mass spectrometry (ESI-MS) and ^{1}H nuclear magnetic resonance spectroscopy, while density functional theory (DFT) calculations further substantiated the PET-based sensing mechanism. DCP5 exhibits excellent sensitivity, with a detection limit of 1.28 nM and a strong fluorescence enhancement observed within minutes at 100 nM FA. In addition, the polymer displays intense solid-state emission, enabling the fabrication of a phosphor-converted light-emitting diode (pc-LED). These results establish DCP5 as a promising platform for FA detection with dual utility in sensing and optoelectronic applications.

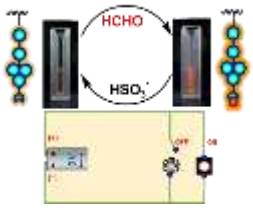


Figure 1. Schematic representation of sensing by the water-soluble polymeric probe with napthalimide pendants.

Keywords: Polymeric sensor; Fluorophore; Formaldehyde; Sensing; pc-LED.

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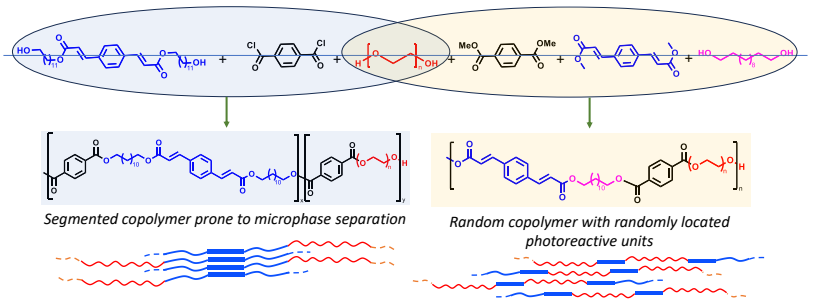
Photo-crosslinked networks – Influence of microphase separation on photocrosslinking

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Photocrosslinking is a useful process to generate network structures for variety of applications. In thin films, the rate and extent of photoreaction will strongly depend on the proximity of the reacting groups; therefore, approaches to design systems that would assist in collocating photoreactive groups is an useful strategy to control photoreactions. *p*-Phenylene diacrylic acid diesters (PDAD) are an interesting class of photoreactive units that carries two photodimerizable cinnamoyl units that could lead to extended photo-stitching; several studies have examined the photo-dimerization of PDAD units in the crystalline state and at air-water interfaces.[1,2] Recently, we utilized suitably installed PDAD units to transform zigzag folded periodically grafted amphiphilic polymers into single-chain nanoparticles via photo-cross-stitching.[3] Earlier, PDAD bearing microphase-separated siloxanes have been explored to create optically anisotropic materials through selective photochemical processing using polarized light.[4]

In this study, two polymeric systems with identical composition, bearing PDAD units, were synthesized via two different strategies; one where the PDAD units are embedded within hydrophobic alkylene segments and copolymerized with PEG600, whereas in the other single step route the alkylene and PEG600 segments are randomly distributed along the chains. The poster will compare the efficacy of photo-stitching in thin films of these two systems to understand the effect of microphase separation on the photoreaction; further, the properties of the crosslinked networks formed in these two systems will be presented to fully comprehend the impact on the properties of the final crosslinked films.



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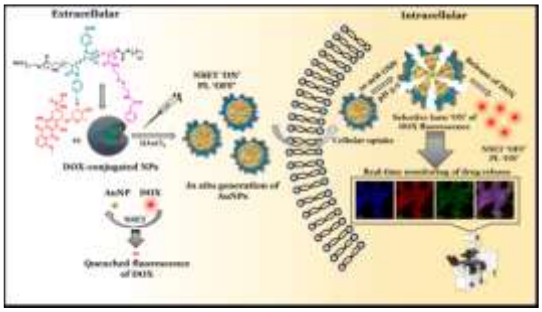
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Theranostic Potential of Raspberry-like Polymer-Gold Nanoconjugates for Cancer Therapy

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Cancer, globally a major health concern, has a surging mortality rate because of the complex tumor microenvironment. To address this complexity, we have designed an integrated platform offering simultaneous diagnosis and treatment. Here, an anticancer drug, doxorubicin (DOX), tethered to bicontinuous polymeric frameworks (P2NPs)[1], provides a unique template for the growth of gold nanoparticles, resulting in an overall raspberry-like morphology (P2AuNPs). The unique nanoconjugate renders an opportunity for the co-delivery of both hydrophobic and hydrophilic drugs to suppress the disease pathway, as well as for imaging purposes. The size and shape of our synthesized gold-conjugated P2AuNPs are ~90 nm, as observed by HRTEM image, and have potential for passive targeting of cancer cells through the EPR effect. The selective drug release at the cancer microenvironment has been monitored by nanoparticle surface energy transfer (NSET) study by pairing doxorubicin and gold nanoparticles, done at acidic pH and high glutathione concentration, allowing real-time monitoring. *In vitro* cellular studies further asserted the selective cytotoxicity of the P2AuNPs against cancer cells.[2] Therefore, our synthesized integrated theranostic system can greatly improve both the accuracy and efficacy of cancer therapy, representing a significant advancement in tailored nanomedicine..



Figures 1 – Graphical abstract

Keywords: Anti-cancer, Nanoconjugates, Nanoparticle Surface Energy Transfer (NSET), Real-time monitoring, Nanomedicine.

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Development of architecture controlled fluorescent polymers for non-linear photo-optic applications

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The molecular theory of macromolecules proposed by Hermann Staudinger in 1920 established the foundation for understanding polymer chains as covalently bonded repeating units, catalyzing a golden era of polymer chemistry characterized by the emergence of materials such as nylon, polyethylene, and polystyrene. Parallel to these advances, polymeric materials were developed with tunable photoluminescence, eco-compatibility, and better mechanical qualities than small fluorophores, i.e., fluorescent polymers, which combined conjugated backbones or pendant fluorophores.[1] Polymers offer multiple sites for functionalization and incorporation of fluorophores, resulting in smart materials capable of stimuli response, selective molecular recognition, and biocompatibility. Fluorescent polymers often exhibit enhanced photoluminescence due to cooperative conformational effects along their macromolecular chains, which amplifies fluorescence signals compared to isolated small molecules. Inherently flawed in solubility, processability, and mechanical brittleness, traditional fluorescent polymeric materials like conjugated polymeric architectures, metal-organic frameworks (MOFs) and covalent organic frameworks (COFs) prevent their incorporation into flexible device platforms, even though their ordered structures allow controlled and unique optical properties.[2] Developing soluble fluorescent polymers with controlled architecture mitigates these problems by permitting facile solution processing, film generation, structural tunability and variable optical characteristics by chemical synthesis, hence boosting applicative scope in optoelectronics, bioimaging, and environmental sensing.[3] Architecture controlled polymers can be processed easily into films, coatings, and flexible devices due to their viscoelastic and mechanical properties, enabling diverse fabrication methods that small molecular fluorophores lack. Moreover, such polymers present unique and interesting aggregation-induced emission effects, bypassing quenching effects inherent in parent fluorophores.[4,5] Innovations in soluble, architecture-controlled fluorescent polymers are set to revolutionize smart sensing technologies, wearable flexible devices, and non-linear photonics. These materials will bridge the gap between molecular design and manufacturable, high-performance optoelectronics.

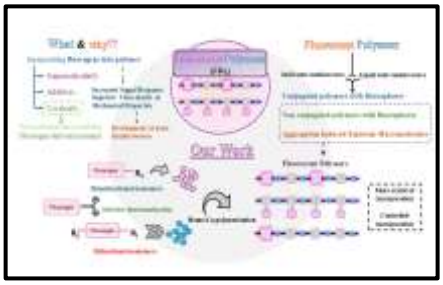


Figure 1. Development of architecture controlled fluorescent polymers.

Keywords: Photoluminescence, Fluorescent, Architecture controlled, Optoelectronics.

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Stereoselective Cationic RAFT Polymerization of Vinyl Ethers (VEs) Using Chiral Additives

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The stereochemical conformation of repeating monomer units in a polymer backbone plays a pivotal role in defining its most important physical and mechanical properties.[1] The ability to control this arrangement significantly influences various polymer characteristics for specific industrial applications, including crystalline melting temperature (T_m), glass transition temperature (T_g), solubility, mechanical strength, chemical reactivity, and morphology.[2] As a result, stereo-controlled polymerization has become one of the major challenges in modern polymer chemistry, offering a powerful route to tailor materials with enhanced performance and targeted functionality for advanced industrial applications. Traditionally, achieving stereoregularity has relied on complex catalytic systems, often involving synthetically demanding chiral ligands or metal complexes.[3] In this work, our central motivation was to develop a simple, practical, and cost-effective catalytic system by employing readily available amino acids as chiral additives. This approach avoids the need for sophisticated catalyst architectures while still enabling effective stereocontrol in cationic RAFT polymerization.[4]

In this study, iso-butyl vinyl ether (IBVE) was chosen as the model monomer to develop a stereocontrolled cationic RAFT polymerization strategy. A chain transfer agent was synthesized via a simple method, ensuring high yield and ease of operation. Polymerizations were carried out using Lewis acid catalysts ($TiCl_4$, $SnCl_4$) with various readily available *α*- and *β*-amino acids as chiral additives. Structural analysis confirmed successful modulation of tacticity, with certain amino acids-especially Boc-protected derivatives-showing significant improvements in stereocontrol. Notably, tacticity strongly correlated with material properties: highly stereoregular polymers exhibited semi-crystallinity and distinct melting transitions, while less ordered samples remained amorphous. All polymers demonstrated excellent thermal stability. The stereoselectivity is attributed to cooperative interactions between the Lewis acid catalyst and the chiral amino acid additive, enabling directional propagation during polymerization. Overall, this work presents a simple yet effective strategy that avoids complex chiral catalyst systems while still achieving enhanced structural definition and performance in vinyl ether polymers.

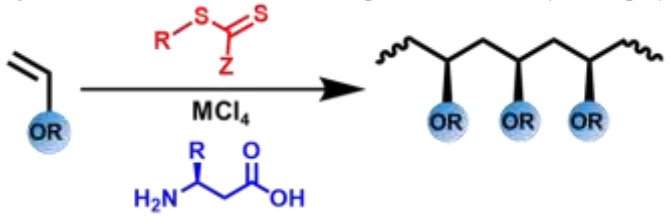


Figure 1: Stereoselective cationic RAFT polymerization of IBVE using amino acid-based chiral additives.

Keywords: Cationic RAFT polymerization; Stereoselectivity.; Chiral additives.; Lewis acid catalysts.; Amino acids.

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Synthesis and Development of Polystyrene-co-hexamethylcyclotrisiloxane and its composite for anticorrosion application

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Copper is a prevalent metal recognized for its superior thermal and electrical conductivity. It is extensively employed in the modern semiconductor industry, serving critical functions in electronic circuits, wiring, cabling, and plumbing applications [1,2]. Despite its inherent corrosion resistance properties, copper surfaces are susceptible to corrosion in corrosive environments, leading to a significant decline in their conductivity [3]. Consequently, it is vital to establish an effective corrosion protection strategy to enhance the longevity of copper-based products. Among various methods, the application of organic coatings has proven to be one of the most effective approaches for mitigating corrosion [4]. In this study, we have synthesized a 1: 1 random copolymer of hexamethylcyclotrisiloxane (D3) and styrene by anionic and ring-opening polymerization using n-butyl lithium as an initiator. The synthesis is a single-step reaction, and both high and low-molecular-weight polymers are obtained from a one-pot reaction. The low molecular weight polymer has better solubility, while the high molecular weight polymer is sparingly soluble. This low molecular weight polymer was applied as a coating material on a copper substrate. This pristine polymer showed good corrosion resistance in chloride, acid, and alkaline environments. Additionally, the low molecular weight polymer is hydrophobic, featuring self-cleaning properties, abrasion resistance, and a hardness rating of 2 H in the pencil hardness test[5]. The corrosion resistance properties of the polymer were enhanced by preparing a series of polyaniline and polymer composites. For this composite coating, four different protonic acid-doped polyanilines were synthesized using hydrochloric acid (HCl), p-toluene sulfonic acid (pTSA), sulfuric acid (H_2SO_4), and phosphoric acid (H_3PO_4) as dopants. Among these, the H_3PO_4-doped polyaniline exhibited better compatibility with the pristine polymer. An electrochemical impedance spectroscopy study revealed that the corrosion resistance properties of the H_3PO_4-doped polyaniline polymer composite coating were ten times higher than those of the pristine polymer. The combination of salt solution diffusion barrier properties of pristine polymer, along with redox-based barrier of PANI against electron transfer reaction from metal surface, plays a synergistic role to maintain an impedance value ($|Z|_{0.01Hz}$) on the order of 10^5 Ω.cm² after 7 days for the 1.0 wt% H_3PO_4-PANI polymer composite.

Keywords: Anionic and ring-opening polymerization, Anticorrosion coating, Self-cleaning, Physical and electrochemical barrier properties, Electrochemical impedance spectroscopy.

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Triazine linked Emissive Porous Organic Polymers for rapid detection of volatile acids

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Designing new porous organic polymers (POPs) with aggregation induced emission (AIE)-active building blocks of paramount interest owing to its potential to yield highly luminescent ***Runa Mondal****POPs. Herein, two new emissive POPs (namely, HVPOP and* ^{t}*BuVPOP) have been developed by taking advantage of pronounced aggregation induced emission (AIE) properties of the partially twisted aryl-substituted buta-1, 3-diene derivatives which are linked through vinylene bond formation with trimethyl triazine. Synthesized POPs are thoroughly characterized by FT-IR and solid-state NMR spectroscopy and their porous nature is confirmed by nitrogen gas adsorption and desorption measurement. Owing to the presence of bulky tert-butyl group in* ^{t}*BuVPOP, it shows relatively higher emission with excellent photoluminescence quantum yield (27.3%) in the solid-state compared to HVPOP (17.9%). A comprehensive photophysical and electrochemical studies for the newly synthesized POPs along with their corresponding monomer units are presented herein. Furthermore, these luminescent POPs are utilized for acid vapor sensing application in the film-state, specifically,* ^{t}*BuVPOP demonstrates an excellent response exhibiting both naked-eye visible color change and significant changes in emission intensity upon exposure to several acid vapors over multiple cycles.*

Keywords: AIE, POPs, PLQY.

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Dual-Stimuli Responsive Amphiphilic Cysteine Copolypeptides: Self-Assembled Carriers for Controlled Delivery.

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The synthesis of functionalized smart polypeptides is particularly challenging, given their remarkable biocompatibility and biodegradability. In this work, we report the synthesize of a dual stimuli-responsive amphiphilic block copolypeptide, [polycysteine-*graf*t-poly(*N*-isopropylacrylamide)-*block*-poly(cysteine-2-nitrobenzyl)] (PCys-*g*-PNIPAM)-*b*-(PCys-NB), which exhibits both thermo- and photo-responsiveness in aqueous media. The synthesis of (PCys-*g*-PNIPAM)-*b*-(PCys-NB) follows a multi-step protocol. In the first step, thiol-mediated polymerization of *N*-isopropylacrylamide (NIPAM) produces cysteine end-capped poly(*N*-isopropylacrylamide) (Cys-PNIPAM). Conventional triphosgene treatment cyclizes the cysteine end group to generate the Cys–PNIPAM N-carboxyanhydride (Cys–PNIPAM NCA). Subsequent ring-opening polymerization (ROP) of Cys–PNIPAM NCA, initiated by hexamethyldisilazane (HMDS), afforded the graft polypeptide, PCys-*g*-PNIPAM. This graft polypeptide acted as a well-defined macroinitiator for a subsequent ROP step, in which the as-synthesized 2-nitrobenzyl-functionalized L-cysteine NCA (Cys-NB NCA) was polymerized block copolypeptide. The sequential polymerization produced the dual stimuli-responsive amphiphilic block copolypeptide, (PCys-*g*-PNIPAM)-*b*-(PCys-NB), containing a thermo-responsive PNIPAM-grafted segment and a photo-cleavable PCys-NB segment. In aqueous solution, the amphiphilic block copolypeptide (PCys-*g*-PNIPAM)-*b*-(PCys-NB) exhibits lower critical solution (LCST)-type soluble-to-turbid phase transition with tunable cloud point (T_{cp}). Upon exposure to UV light ($\lambda = 350$ nm), the amphiphilic block copolypeptide (PCys-*g*-PNIPAM)-*b*-(PCys-NB) undergoes photocleavage of the 2-nitrobenzyl protecting groups, leading to the formation of the more hydrophilic derivative (PCys-*g*-PNIPAM)-*b*-(PCys-COOH). This structural transformation significantly alters the overall hydrophilic–hydrophobic balance of the copolypeptide, thereby enhancing its solubility in aqueous media. This enhanced hydrophilicity raises the cloud point temperature (T_{cp}), indicating improved water compatibility of the polymer after UV irradiation. In aqueous media, the amphiphilic (PCys-*g*-PNIPAM)-*b*-(PCys-NB) forms vesicular nanoaggregates, as confirmed by dynamic light scattering (DLS) and transmission electron microscopy (TEM). These nanoaggregates are capable of encapsulating a Nile Red hydrophobic dye from the solution as confirmed by spectroscopic and confocal microscopic studies. When exposed to UV light, the photocleavage of NB segments causes an imbalance in the hydrophilic/hydrophobic characters in the pristine block copolypeptide. Light treatment disrupts the assembly of the (PCys-*g*-PNIPAM)-*b*-(PCys-NB) in aqueous solution. This disruption in the vesicular morphology of the (PCys-*g*-PNIPAM)-*b*-(PCys-NB) causes the release of the encapsulated dye/drug into the bulk.

Keywords: ROP, Polypeptide, Thermo-responsive, Photo-responsive, Vesicular.

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Swelling Behavior of Double Network Hydrogel

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Hydrogels are three-dimensional networks that can retain a large amount of fluid. Conventional hydrogels often suffer from poor mechanical properties. [1] These issues emanate from imperfections present in the single network leading to un-even crosslinking density and non-homogenous swelling. [2]

A new class of materials, known as tough hydrogels, show significantly superior mechanical properties compared to their conventional counterparts. Double network (DN) hydrogels are a type of tough hydrogels that consist of two interpenetrating networks. [3] The first network has a high crosslinking density and is composed of a polyelectrolyte, while the second network has a low crosslinking density and is composed of a neutral polymer. The synergy between the brittle first network and a flexible second network results in the dissipation of energy at the expense of the brittle network and therefore, the DN hydrogels can sustain large loads without failure.

There is enough evidence suggesting that the swelling of the first network plays a critical role in dictating the overall mechanical properties of the DN hydrogels. However, a systematic study of the swelling behavior, specifically for the first network, is missing. This work aims at understanding the mechanical behavior of DN gels by modulating the swelling of the brittle network.

Keywords: Double network hydrogel (DN).

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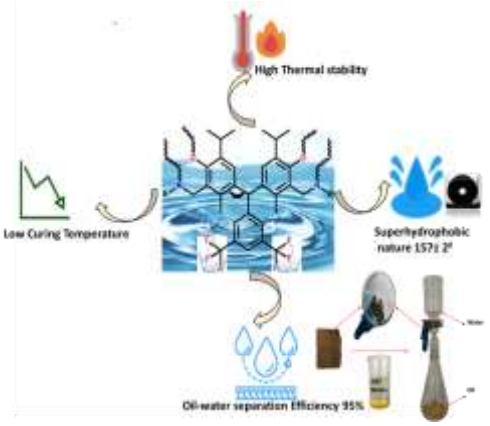
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A Novel Fluorinated Polybenzoxazine Matrix for Thermal Resistant and Hydrophobic Coating Applications

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An attempt has been made to develop a novel series of fluorinated polybenzoxazine matrices with superhydrophobic behaviour for advanced oil–water separation applications[1,2]. A key precursor, 4,4′-((3,5-bis(trifluoromethyl)phenyl)methylene)bis(2-isopropyl-5-methylphenol) (BPMP), was synthesized by the condensation of thymol with 3,5-bis(trifluoromethyl)benzaldehyde at 100 °C. Four benzoxazines (BPMP-ffa, BPMP-an, BPMP-ean, and BPMP-atu) were subsequently obtained through Mannich condensation of BPMP with furfurylamine, aniline, 3-ethynylaniline, and allylthiourea, respectively, in the presence of paraformaldehyde. The fluorinated aromatic core, combined with various substituent groups, imparts low surface energy and enhances hydrophobicity in the resulting polymers. Structural confirmation of the synthesized monomers was carried out using FT-IR, ^{1}H,^{13}C-NMR, and mass spectrometric analyses. DSC data revealed curing temperatures ranging from 177°C to 276°C, which varied with the electronic effects of the substituents. TGA demonstrated char yields between 12% and 32%, with poly(BPMP-an) exhibiting the highest thermal stability and residue. Surface analysis showed that poly(BPMP-an) possessed a water contact angle of 157°, indicative of excellent super-hydrophobicity. This property intended to study oil-water separation which shows on efficiency of 95 %. The findings affirm that BPMP-derived polybenzoxazines are novel, durable, and versatile materials, offering significant potential for high-performance coatings and separation technologies under demanding environmental conditions.



Keywords: BPMP, Fluoro core polybenzoxazines, super-hydrophobic, thermal stability.

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Non-Conventional Clusteroluminescence from Unconjugated Poly(2,3-dihydrofuran)

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In recent times, non-conventional luminescent polymers have attracted considerable attention as promising alternatives to traditional fluorescent polymers, offering solutions to many of their inherent limitations.[1] Unlike conventional luminescent systems, these materials display unique emissive properties even in the absence of traditional chromophores or π-conjugated structures, making them fascinating for both fundamental science and application-driven research.[2] In this study, we report a new class of non-conjugated polymers derived from 2,3-dihydrofuran (DHF), which exhibit bright emission in both solid and solution states despite the absence of conjugation or conventional chromophores (Figure 1). Poly(2,3-dihydrofuran) (PDHF) samples with varying molecular weights were synthesized *via* cationic polymerization. These polymers display excitation-dependent emission, which indicates the presence of multiple emissive states,[3] a feature that is uncommon in conventional fluorophores where both the ground and excited states are typically fixed. On the other hand, dilute PDHF solutions display only weak luminescence, but the emission intensity increases significantly with concentration, suggesting the absence of the aggregation-caused quenching (ACQ) effect that is common in traditional chromophores. Moreover, a marked enhancement in fluorescence intensity was observed for PDHF solutions in THF upon the addition of non-solvents such as hexane and water, thereby confirming their characteristic aggregation-induced emission (AIE) behavior.[4] In addition to their intriguing luminescent properties, PDHF polymers possess an inherent transparency in the visible region. This feature opens exciting opportunities for practical applications. For instance, thin films of PDHF can be fabricated that appear completely invisible to the naked eye under normal ambient light, yet exhibit bright fluorescence when exposed to UV irradiation. This unique transparent–emissive duality renders these polymers highly appealing for advanced optical and security-oriented applications, such as the fabrication of invisible inks that allow discreet writing of messages, markings, or security codes. These inscriptions remain undetectable under normal lighting but reveal bright fluorescence upon UV exposure, providing an effective strategy for anti-counterfeiting, data encryption, and the development of smart packaging and labeling technologies.[5]

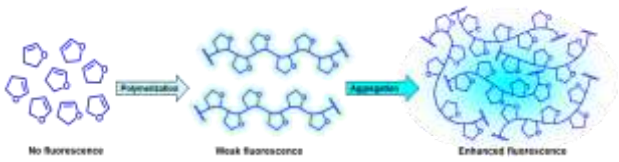


Figure 1. Nonconventional luminescence behavior of PDHF.

Keywords: Cationic polymerization, 2,3-Dihydrofuran, Non-conventional fluorophore, Aggregation induced emission (AIE), Clusteroluminescence.

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A Thioether-Functionalized Biomimicking Polyoxazoline Platform: Expanding the Horizons of Thermo-/Photo-/Anion-/ROS-responsive Pseudopolypeptide

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Extensive functionalization has made poly(2-oxazoline)s (POx)s highly versatile; however, the controlled incorporation of thioether side chains into POx architectures remains a significant synthetic challenge. This challenge primarily arises from the nucleophilic nature of the thioether moiety, which can trigger undesired side reactions and chain termination during cationic ring-opening polymerization (CROP). Herein, we report an elegant synthetic route to a rationally designed oxazoline monomer, 2-(2-(methylmercapto)ethyl)-2-oxazoline (MMPOx) from 3-mercaptopropanoic acid, along with an optimized CROP protocol that enables its successful polymerization into well-defined poly(2-(2-(methylmercapto)ethyl)-2-oxazoline) (P(MMPOx)) architectures. This precise structural mimicry of polymethionine imparts thermoresponsive properties for this pseudopolypeptide, exhibiting an upper critical solution temperature (UCST)-type phase transition behavior in organic-water mixed solvents. The cloud point (T_{CP}) of P(MMPOx) systematically decreases with increasing ethanol content. Furthermore, the presence of side-chain thioether group allows strategic post-polymerization modification with 2-nitrobenzyl bromide to yield a cationic polysulfonium architecture (P(MMPOx)-NB). This modification renders the cationic polymer water-soluble and introduces diverse functionalities, including photo-responsiveness, anion responsiveness (such as, I^-, ClO_4^-, and SCN^-), and facile DNA polyplexation, thereby facilitating its application in gene delivery systems. The aqueous solution of P(MMPOx)-NB showed transitions from transparent to turbid upon the addition of these anions, and the turbid suspension reverts to transparent upon heating, confirming a reversible UCST-type phase behaviour. The photolabile nitrobenzyl group is responsible for the cationic character of the P(MMPOx)-NB, consequently, photo-irradiation triggers a charge-reversal process, reverting the cationic polymer into its water-insoluble neutral analog, i.e., parent P(MMPOx). This change facilitates the binding and release of DNA, as corroborated by gel electrophoresis and photoluminescence studies using an ethidium bromide (EtBr) intercalator assay. Although photo-induced insolubility could limit its utility, the inherent ROS-responsiveness of the thioether group provides a secondary mechanism to revert the hydrophobic polymer into a water-soluble hydrophilic one, thereby enhancing its suitability as non-viral genetic delivery. Furthermore, the compaction of DNA by the cationic polymer, a necessary step for endosomal escape, was confirmed by measuring the Förster Resonance Energy Transfer (FRET) efficiency between a FRET pair (FAM-TAMRA) tagged to DNA. By establishing a robust platform for thioether-functionalized POx, this work unlocks their potential as multifunctional, stimuli-responsive polymers for advanced biomedical applications.

Keywords: CROP, Poly(2-Oxazoline), Multi-stimuli responsive, DNA polyplexation, non-viral delivery system.

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"Smart" Poly(ionic liquid)s Derived from Functional Ionic Liquid Monomers and via Post-polymer Modification: From Antifouling Agent to DNA Polyplexation

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Functional Ionic Liquid Monomers (ILMs) are used to create advanced Poly(ionic liquids) (PILs). Also, via post-polymer modification, PILs can be achieved. This work describes the synthesis of two novel monomers: carboxyalkylbenzimidazolium bromide-functionalized zwitterionic monomers (ZILMs) and long alkyl-chain cationic ILMs with styryl and methyl methacrylate backbones, respectively. These monomers are polymerized using reversible addition-fragmentation chain transfer (RAFT) and free radical techniques.[1] The resulting poly(zwitterionic ionic liquid)s (PZILs) exhibit pH- and ion-responsive and UCST-type phase behavior in water, acting as cationic PILs below their isoelectric points to effectively disperse multiwalled carbon nanotubes into responsive nanocomposites. They also show anti-protein-fouling behavior and can be used to form hydrogels with swelling properties precisely controlled by pH and temperature. The study further investigates how alkyl chain length and counter-anions influence the thermal and crystalline properties of long alkyl-chain PILs, finding that bromide-based PILs in chloroform display UCST-type phase transition behavior and self-assemble into nanovesicles capable of encapsulating dye, demonstrating their potential for targeted delivery systems.[2] Furthermore, our work focuses on optimization of the controlled cationic polymerization of ethyl vinyl sulfide (EVS), initiated by $FeCl_3$ and HCl-adduct of the monomer (EVS-HCl), in conjugation with tetrabutylammonium bromide (TBAB) and ethyl acetate (EtOAc) as a stabilizing base for $FeCl_3$. PEVS is modified with long-chain 1-bromoalkanes and 2-nitrobenzyl bromide to yield semicrystalline and photo-responsive PILs, respectively. A representative, $^{n}C_{16}H_{33}$-tagged PEVS-based PIL successfully debundles multi-walled carbon nanotubes (MWCNTs) in $CHCl_3$ and the formed PIL-MWCNT composite dispersion is stable up to 48 h. Aqueous solution of the 2-nitrobenzyl bromide-tagged PIL shows Hofmeister's anion (SCN^-, BF_4^-, and ClO_4^-)-induced upper critical solution temperature (UCST)-type reversible phase behaviour. However, in presence of I^-, instead of such physical phenomenon, dealkylation takes place at elevated temperature. Due to high cationic charge (ζ = +50 mV), this PIL is found to be very efficient in polyplexation with ctDNA. On irradiation with ultraviolet light, ctDNA is released from the polyplex. Furthermore, PEVS is reacted with 1,3-propansultone to yield a water-soluble poly(zwitterion) (PZ), capable of resisting nonspecific adsorption of BSA protein.

Keywords: Poly(ionic liquid)s, Stimuli-responsiveness, Antifouling agents, Semicrystallinity, DNA polyplexation.

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RAFT-Synthesized Citrulline-based Polymethacrylates: UCST-Tunable Systems for Dye Encapsulation and FITC-Labeled LCST Conjugates

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Amino acid-based stimuli-responsive polymers have attracted huge attention as potential biomaterials for drug delivery, tissue engineering and antifouling coating due to their interesting physicochemical properties and inherent biocompatibility. In the case of non-canonical amino acid (ncAA)-derived polymers, they contain specific functional groups that exhibit unique chemical and physical properties not found in canonical amino acids (cAAs). Therefore, ncAA-based polymers are expected to exhibit interesting stimuli-responsive behaviors with potentiality as biocompatible biomaterials for drug delivery, tissue engineering, and antifouling coatings. Hence, this research aims to develop a ncAA, L-citrulline-based polymers containing a 'ureido' group exhibiting thermoresponsive behavior under physiologically relevant conditions. We have designed and synthesized a Boc-L-citrulline-based methacrylate monomer (Boc-cit-EMA) by coupling of hydroxyethyl methacrylate (HEMA) with Boc-protected L-citrulline that polymerized via RAFT technique to produce poly(Boc-cit-EMA). The detailed kinetic studies confirmed first-order behavior up to high monomer conversions with controllable molecular weight (M_n) and dispersity ($Đ$). P(Boc-cit-EMA) is soluble in aliphatic alcohols and various polar organic solvents. Upon decreasing temperature, the transparent aliphatic alcoholic solution of P(Boc-cit-EMA) became turbid and transparent upon heating indicating its reversible UCST-type phase behaviours. Cloud point (T_{cU}) increases systematically with the increase of the alkyl chain length of the respective alcohols. P(Boc-cit-EMA) is insoluble in water; however, the addition of water to its alcoholic (aliphatic) solutions results in turbidity, which disappears reversibly upon heating, thereby confirming UCST-type behavior. As the water content increases, T_{cU} values increases as monitored via UV and DLS. T_{cU} in neat alcohols and alcohol-water mixtures can be tuned by altering polymer concentration, M_n, type of aliphatic alcohols and water content. UCSTs in alcohol-water mixtures are higher than those in neat alcohols. P(Boc-cit-EMA) in both cases, formed insoluble spherical nanoaggregates that monitored via FESEM. Furthermore, P(Boc-cit-EMA) in both alcohol and alcohol-water mixture, effectively encapsulates Nile Red during aggregation below the T_{cU}, forming insoluble dye-loaded particles, as examined by confocal microscopy and TCSPC technique. P(Boc-cit-EMA) is a hydrophobic molecule, but after Boc-deprotection, it became soluble in water. The conjugation of fluorescein isothiocyanate (FITC) to Boc-deprotected P(cit-EMA) yielded a water-soluble fluorescent conjugate displaying LCST-type behaviour in water and formed insoluble '*wild sugarcane*' like dendritic structures above cloud point. These dendritic structures were examined through FESEM and confocal microscopy. These conjugates are expected to be useful in applications as an effective sensory material or a bioimaging probe.

Keywords: RAFT, UCST, LCST, Dye encapsulation, Fluorescent conjugate.

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Designing and development of styrene crosslinked curcumin derivative gel as a drug delivery system

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Curcumin, a natural polyphenolic compound, is a highly valuable bioactive agent with diverse applications, particularly in the biomedical field, owing to its potent antioxidant, anti-inflammatory, and antimicrobial properties. The creation of polymer networks from monomers like styrene and divinylbenzene (DVB) has been a common approach. However, the conventional crosslinker such as DVB have significant drawbacks, including their petroleum-based origin, associated toxicity, and non-biocompatible nature. To address these limitations, we utilized a novel bifunctional derivative of curcumin to create a bio-based crosslinker, which was then employed to fabricate a novel styrene-based organogel. The successful formation of the crosslinked network was confirmed by Fourier-transform infrared (FTIR) spectroscopy. A comprehensive comparative analysis between the new curcumin derivative-crosslinked gel and a traditional DVB-crosslinked gel was conducted using thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), X-ray diffraction (XRD), and field emission scanning electron microscopy (FE-SEM). The results show that the curcumin derivative-crosslinked gel exhibits enhanced thermal stability, a distinct semi-crystalline morphology, and a significantly higher swelling capacity in organic solvents. These superior properties are attributed to the flexible and polar nature of the curcumin derivative, confirming its potential as an excellent material for applications in controlled drug delivery offering a sustainable and high-performance alternative to conventional polymer systems.

Keywords: Curcumin derivative, Styrene organogel, Cross-linker, Thermal stability, swelling behavior.

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Synthesis and Self-assembly of Polythiourethane with Cationic Pendant Groups for Antibacterial Applications

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Antimicrobial resistance infections (ARIs) will cause more than 10 million deaths annually by 2050, significantly outnumbering deaths from all malignancies and AIDS combined, according to the U.S. Centers for Disease Control (CDC). Multidrug-resistant (MDR), gram-positive infections, and the ongoing COVID-19 epidemic are critical global morbidity and mortality determinants. MDR infection is a worldwide health issue. Antimicrobial polymers, designing a new class of molecules, are inspired by the host-defence antimicrobial peptides (AMPs) and functionalized with cationic groups that may rupture microbial membranes and prevent the formation of biofilms. With a few exceptions, the peptide sequence of AMPs is rich in cationic and hydrophilic amino acid residues. The bacterial cell membrane mainly consists of negatively charged compounds. In contrast, the outer leaflet of the mammalian cell membrane is zwitterionic in nature. Thus, the cationic groups of AMPs preferably interact with the negatively charged bacterial membrane over the zwitterionic mammalian membrane, which makes the selective killing of bacteria possible. In this regard a few advancement took place where they utilized cationic polyurethane for antibacterial applications.[1,2] Where as polythiourethanes (PTU) are made in a more environmentally friendly manner than typical polyurethane synthesis, which uses isocyanates, which are hazardous since they are prepared by phosgene[3].

In this project, we have developed synthetic polymers as promising AMP mimic by varying ammonium groups in the pendant polymer chain. The amphiphilic polymers were synthesized by step-growth polymerization of dithiocarbonate (DTC) and diamine. The thiols group produced from the ring opening of DTCs was used to conjugate different amine derivatives using the Thiol-Michael addition reaction by reacting them with corresponding acrylates. The effect of the linker on self-assembly and antibacterial effect was understood by synthesizing two different types of polymers with aliphatic (ALP) and aromatic (ARM) backbones. Six polymers with DP in the range of 13-15 are classified into two groups depending on the linker in the polymer backbone (ALP and ARM), each with three different pendant amino groups. All the polymers were characterized by ^{1}H NMR, ^{13}C NMR, FT-IR, and HR-MS. Degree of polymerization or number average molecular weight was estimated from ^{1}H NMR and size-exclusion chromatography. In addition, the polymersome formation was confirmed by encapsulating the hydrophilic dye calcein. The absorbance-normalized emission intensity of calcein was significantly reduced compared to that observed for the free dye, which can be attributed to self-quenching of the dye in the confined water-filled lacuna of the vehicle. The presence of a cavity inside the aggregates makes them appealing for encapsulating hydrophilic and hydrophobic drugs. Encapsulation efficiency of hydrophilic dye calcein was estimated to be in the range of 15-20%. Antibacterial activity against various gram-positive and gram-negative bacteria were tested. Additionally, toxicity against human red blood cells was evaluated.

Keywords: Antimicrobial polymers, step-growth polymerization, self-assembly, polymersome, antibacterial activity.

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Titanium(IV) Complexes Featuring Fluorenyl-Tethered Oxazoline Ligands: Design, Synthesis and Catalytic Performance in Ethylene Polymerization

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Since the discovery of homogeneous group IV metallocene catalysts in the 1980s,[1] significant effort has been directed toward tuning catalyst structure to enhance olefin polymerization activity and tailor polymer properties such as stereoregularity, co-monomer incorporation, and microstructure.[2,3] Beyond conventional bis(cyclopentadienyl) systems, considerable attention has turned towards hybrid architectures incorporating one Cp-type ligand and a second, non-Cp donor ligand bridged or unbridged to the Cp moiety. In this context, oxazoline ligands are especially attractive because their strong N-donor character enables effective coordination to group 4 metal ions in their higher oxidation state of +4.[4] While oxazoline ligands are widely recognized for their importance in asymmetric catalysis, their application in olefin polymerization has been comparatively less explored. In the present work, we focus on the development of indigenous C1-bridged fluorenyl-oxazoline ligands with systematically varied alkyl substituents at the bridging carbon atom. These ligands were synthesized and converted to the corresponding half-metallocene Ti(IV) complexes by reacting with $TiCl_4$. Upon activation with TIBA/borate cocatalyst systems under atmospheric pressure (Schlenk conditions), they showed ethylene polymerization activities and resulting in the formation of UHMWPE. In this poster presentation, the ligand design, synthetic strategies and structural features of the titanium complexes, along with their polymerization performance and structure-activity correlations will be discussed.



Keywords: Fluorenyl-substituted oxazoline ligands, Titanium(IV) complexes, Half-Metallocene, Ethylene, Polymerization.

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Silver Nanoparticles - Enhanced Activated Carbon Fabric from Non-woven viscose rayon for Mustard Gas Adsorption

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Non-woven viscose rayon(regenerated cellulose) has been used for preparing Activated carbon fabric (ACF) which is porous and have high absorbency for hazardous chemicals.[1] To incorporate antibacterial property modification is introduced onto the fabric surface by in-situ doping of silver nanoparticles (AgNPs).[2] The effect of variation in activation temperature and the reaction time on the chemical properties and microstructure of silver-containing activated carbon fabric (ACF-Ag) absorbents are investigated.Silver doping is carried out on the non-woven viscose rayon fabric before carbonization, after carbonization and after activation by in-situ synthesis reaction. The structural characterization of the ACF-Ag was carried out using a combination of Fourier transformed infrared (FTIR), X-ray diffraction (XRD), Thermo gravimetric analysis (TGA), and Scanning Electron Microscopy (SEM). Results, have shown that a ACF adsorbents which had more activation time (90min) had high surface area of 1761.495 m^2/g (based on the formula of multilayer absorption by Brunauer Emmett Teller). Scanning Electron Microscopy (SEM) images revealed that the surface of the modified non-woven viscose rayon was rougher than that of normal cotton. It shows the presence of AgNPs on the surface of treated fabric. In Fourier transformed infrared (FTIR), the spectra of silver nano coated cotton fabric doesn't reveal new peak which means that no chemical reaction on cellulose takes place during the in-situ coating of AgNPs and in X-ray diffraction (XRD) shows amorphous nature of ACF and when modification is done with AgNPs broader peak which shows crystalline nature.

Keywords: Silver Nanoparticles (AgNPs), Activated carbon fabric (ACF).

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Stereocomplex Polylactide Formation through Hydrogen-Bonding Organocatalyzed Ring-Opening Polymerization of Racemic Lactide

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Precise control over stereoregularity and sequence distribution in polymeric materials is a powerful strategy to tailor their physical properties and expand their application potential.[1-3] Organocatalytic ring opening polymerization[4] (ROP) has emerged as an attractive approach for the synthesis of biodegradable polyester, particularly polylactides (PLAs), which are considered sustainable alternatives to petrochemical based plastics with broad biomedical relevance.[5] Here, we report an organocatalytic strategy for the enantioselective ROP of racemic lactide using a newly designed Organocatalyst (Figure 1). This catalyst enables polymerization under ambient conditions, affording semicrystalline PLA with a probability of meso linkages (P_m) of 0.69. Remarkably, lowering the polymerization temperature enhances stereocontrol, yielding highly isotactic PLA (P_m = 0.96). The polymerizations proceed in a highly controlled fashion, as demonstrated by a linear correlation between molecular weight and monomer conversion, narrow dispersity ($Đ$ = 1.05), and excellent chain-end fidelity. Bulk Characterization of obtained PLA like Differential Scanning Calorimetry (DSC), Solid state Fourier Transform Infrared (FTIR) Spectroscopy and Wide-Angle X-ray Scattering (WAXS) is under investigation.

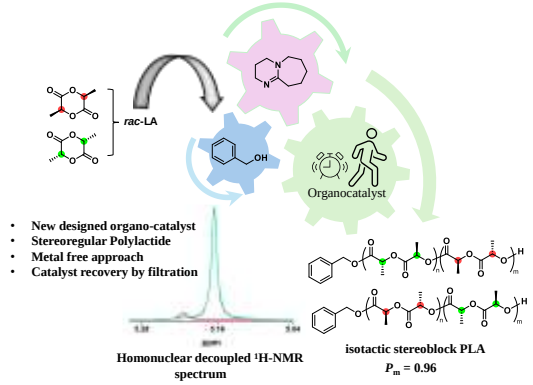


Figure 1. Schematic Representation of Stereoselective Ring Opening Polymerization (ROP) Of racemic-Lactide.

Keywords: Biodegradable, Stereoselective, Tacticity Control, Polylactide (PLA), Stereocomplex PLA.

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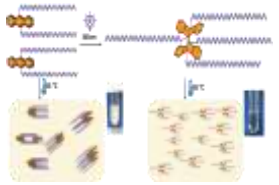
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Modulating Thermoresponsive Properties of Poly(L-proline) through Anthracene Dimerization

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Proline is a special amino acid with structural features that make it different from all other natural amino acids. Because of its cyclic side chain and the absence of an amide proton, proline mainly adopts the polyproline II (PPII) conformation, which is stabilized by a non-covalent n–π* interaction[1]. It can also switch between two helical states: the right-handed polyproline I (PPI) and the left-handed polyproline II (PPII). These conformations depend strongly on hydration and temperature. At lower temperatures, the PPII helix is stabilized by water molecules through hydrogen bonding, but as the temperature increases, dehydration occurs, which destabilizes the structure and leads to conformational changes, aggregation, and eventually phase separation. This unique behavior gives poly(L-proline) (PLP) its thermoresponsive properties, making it highly attractive for applications in drug delivery, nanotechnology, tissue engineering, and biotechnology. The thermoresponsive properties of PLP can be tuned by changing external conditions such as the ionic strength[2] of the solution or by attaching functional groups that are either hydrophilic or hydrophobic[3,4]. In this work, we explored a different strategy by synthesizing anthracene-functionalized poly(L-proline) (ANT–PLP), where the initiator contains an anthracene group that can undergo reversible dimerization upon light irradiation. ANT–PLP samples with chain lengths of 34, 50, 72, and 100 units were synthesized and studied using ^{1}H NMR and UV–Vis spectroscopy. The experiments confirmed successful functionalization and revealed clear structural and thermoresponsive differences between monomeric and dimerized forms. Importantly, anthracene photo-dimerization increased the cloud point temperature (T_{CP}) and altered the conformational transitions of PLP (Figure 1). These findings show that light-controlled anthracene dimerization offers a powerful and tunable approach to regulate PLP's thermosresoponsive behaviour. This work demonstrates a pathway for developing photoresponsive biomaterials with programmable phase behavior that can be applied in advanced biomedical fields.



Keywords: Polyproline, Thermoresponsive, Photoresponsive, Anthracene dimerization.

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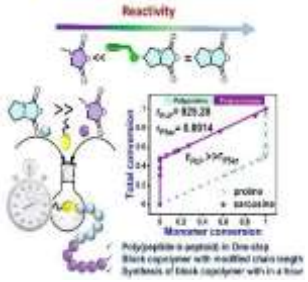
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Synthesis of sequence-controlled polymers via a one-pot kinetically tuned method and comparison of their secondary structures

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Proteins achieve their complex biological functions through their unique three- dimensional structures, determined by the precise sequence and spatial orientation of monomers[1]. Inspired by nature's structural control, researchers have sought to bridge the gap between the architectural precision of biomacromolecules and the randomness of synthetic polymer chains[2]. Solid-phase peptide synthesis[3] has advanced the creation of sequence-defined natural and non-natural macromolecules, yet scalability, functionalization, and restricted polymer growth on solid supports pose challenges. Bio-inspired methods, including genetic engineering, enable sequence-defined biopolymer synthesis but remain limited to biological systems. Among synthetic polymers, block copolymers prepared through controlled or living polymerization have garnered significant attention. Traditional sequential polymerization, while effective, is labor-intensive and limits large-scale synthesis. Emerging single-step strategies, such as one-pot sequential polymerization, switchable polymerization, orthogonal chemistry, and kinetically controlled processes, promise efficient synthesis of block copolymers. Kinetically controlled methods, in particular, offer versatility in tailoring copolymer structures, including alternating and gradient forms[4]. These processes leverage monomer reactivity ratios, governed by intrinsic homopolymerization and copolymerization kinetics, to dictate sequence control and expand the potential of synthetic polymer design. We developed a one-pot synthesis approach for polypeptide-b-polypeptoid block copolymers by leveraging the reactivity differences between carefully selected N-carboxyanhydride (NCA) monomer pairs. This strategy enabled the efficient, one-step preparation of well-defined block copolymers, including poly(L-proline)-*b*- polysarcosine (PLP-*b*-PSar) and poly(propargyl-L-proline)-*b*-polysarcosine (PLPP-*b*-PSar). Kinetic studies using ^{1}H NMR confirmed the formation of sequence-controlled primary structures in a one-pot synthesis. The analysis showed significant differences in reactivity ratios between the monomer pairs ($r_{PLP} = 925$, $r_{PSar} = 0.0014$; $r_{PLPP} = 860$, $r_{PSar} = 0.0015$), which facilitated the one-pot block copolymerization (Figure 1). Interestingly, the secondary structures and thermal stability of these copolymers were found to closely resemble those of block copolymers synthesized via traditional sequential addition methods. This highlights the efficiency and practicality of the one-pot approach, demonstrating its potential for producing advanced functional bio-materials with well-defined secondary structures[5].





Keywords: Sequence control polypeptide, One-pot synthesis, Poly(peptide-b-peptoid), secondary conformation.

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Tuning the core of aromatic polyamides by linkage isomer to reinforce the secondary structure

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Natural biomolecules such as proteins and DNA adopt precise three-dimensional structures, inspiring the development of synthetic analogues known as foldamers. These artificial systems are designed not only to mimic natural folding patterns but also to achieve new functions beyond those found in biology. Folding in foldamers is typically governed by noncovalent interactions, including hydrogen bonding, π–π stacking between aromatic rings, solvophobic effects, and metal–ligand coordination. A variety of synthetic foldamers have been reported, adopting structural motifs such as single helices[1], double helices[2], one-dimensional pleated sheets[3], and molecular tweezers. Several design strategies have been employed, including aryl acetylenes, donor–acceptor assemblies (e.g., 1,5-dialkoxynaphthalene and naphthalene diimide), and aromatic oligoamides, the latter being especially promising. Aromatic oligoamides, however, suffer from free rotation about amide bonds, producing two partially coplanar conformations of similar stability that hinder the establishment of well-defined secondary structures. To overcome this, Hamilton and co-workers introduced intramolecular hydrogen bonds to restrict rotation and stabilize specific conformations. Building on this, our group previously demonstrated the formation of intrachain β-sheet-like structures in aromatic polyamides, stabilized cooperatively by intramolecular hydrogen bonding and π–π stacking[4].

In this report, we successfully synthesized a series of periodically propargyloxy-functionalized aromatic polyamides of appreciable molecular weight, incorporating either pyrene or naphthalene core unit via step-growth polymerization. Preliminary investigations using model compounds revealed that, among the two key noncovalent motifs considered (hydrogen bonding and π–π stacking), π–π stacking between adjacent pyrene diamide units plays the dominant role, driving the folding of the polymer chains into compact architectures.

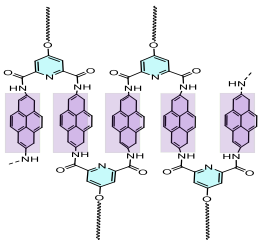


Figure 2: Schematic representation of periodically propargyl-functionalized aromatic polyamides.

Keywords: Foldamers, Aromatic polyamide, π–π stacking, hydrogen bonding.

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Synthesis and Characterization of Disulfide-Containing Poly(urethane-urea) for Self-Healing Applications

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Self-healing polymeric materials have gained significant interest due to their ability to autonomously repair damage, preventing catastrophic failures and prolonging the lifespan of the material [1]. The incorporation of disulfide linkages into a polymer backbone imparts reversible bond exchange under stimuli like heat, light exposure, or moisture [2][3]. While most recent studies use disulfide bonds as crosslinkers or chain extenders, a novel disulfide-containing poly(urethane-urea) (PUU) was synthesized, where the disulfide bond is integrated into the polymer backbone to increase self-healing properties, and urethane-urea linkages can form strong hydrogen bonds to enhance the mechanical properties. The synergistic effect of both hydrogen bond and disulfide-bond exchange leads to faster and efficient self-healing [4][5]. The PUU polymer was synthesized using a disulfide-based polymer with methylene diphenyl diisocyanate (MDI) and 4,4'- diaminodiphenylmethane (MDA) in a molar ratio of 1:1.1:1. The self-healing of the PUU was studied by making a scratch on the film using a laser blade with a width and depth of the scratch of 15 and 0.7 μm, respectively., Then the scratch of the film was healed at 100 °C within 7 min, which was observed by atomic force microscopy and optical microscopy. For the tensile test, a few dumbbell-shaped specimens were taken from the film with 13 × 2 × 0.5 mm dimensions and were scratched up to 0.4 mm depth and healed at 100 °C. The resulting film exhibited excellent mechanical properties before and after self-healing, with a self-healing efficiency of 44%. A complete recovery of the storage modulus was observed up to the fifth cycle in the presence of strain 0.1% to 100% at 100 °C, as evidenced by rheological tests. The facile synthesis method and good self-healing as well as self-recovery properties demonstrate that this polymer can be used for self-healing applications.

Keywords: Self-healing, disulfide bond, poly(urethane-urea), hydrogen bond, disulfide-bond as crosslinkers or chain extenders.

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A review on polyphenylene oxide-based membranes used in Anion Exchange Membrane Water Electrolysis for green hydrogen production

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Anion Exchange Membrane Water Electrolysis (AEMWE) has proven to be a promising technology that combines the efficiency of proton exchange systems with the cost advantages of alkaline electrolysis to produce green hydrogen. Anion exchange membranes (AEMs) are a critical part of AEMWE, and so intensified research into new materials for developing durable and high-performance AEMs capable of operating under alkaline conditions is a key challenge.[1] Among the various polymer candidates, poly(2,6-dimethyl-1,4-phenylene oxide) (PPO) membranes have gained significant attention due to their good thermal stability, chemical resistance, functionalization adaptability, adjustable chemical structure, film-forming properties, and favorable alkaline stability.[2] This review summarizes recent advances in the design, modification, and performance of PPO-based AEMs that are tailored to fabricate membrane-electrode assemblies (MEAs) for AEMWE applications. The methodology to enhance hydroxide conductivity and mechanical integrity involves backbone functionalization through bromination and quaternization, cross-linking with azonia-spiro structures, and blending with polyethylene glycol (PEG).[3] Ether-free aromatic PPOs and hydrophobic segment incorporation (e.g., TFP-based monomers) have demonstrated marked improvements in membrane conductivity (>160 $mS.cm^{-1}$ at 80 °C), mechanical strength (>25 MPa), and operational durability (>1,000 h at 1 $A.cm^{-2}$ in alkaline electrolyzers).[4] PPO's resistance to alkaline degradation has increased due to developments in crosslinking techniques, surface modification, and molecular design. This paper identifies potential directions for PPO AEM development to optimize water management, enhance interfacial compatibility with non-precious metal catalyst layers, and achieve long-term cation stability under high pH and elevated temperature conditions. Scalable fabrication techniques and cost-effective synthesis procedures are also essential for the commercial viability of functionalized PPO derivatives.[2] PPO-based membranes give AEMWE systems their durability and efficiency, making them a viable choice for future green hydrogen technologies.

Keywords: Anion Exchange Membrane Water Electrolysis, Polyphenylene oxide, Hydroxide conductivity, Membrane electrode assembly.

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Zwitterionic Self-immolative Block Polymers of Poly(amino-ester)s and Polycaprolactones

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Synthetic macromolecules having self-immolative characteristics are important class of biomaterials owing to their unique ability to undergo degradation under physiological pH into non-toxic oligomers while employ them in biomedical applications. Among the self-immolative polymers, poly(amino esters)s (PAE)s (both □ and □ derivatives) have special place because of their unique auto-degradation mechanism under physiological pH=7.4 by the nucleophilic attack of the amine on the ester-carbonyl atom (see Figure 1a). Under acidic pH < 4.0, the protonated amine does not undergo nucleophilic attack; however, at neutral pH, the amine (in the de-protonated form) rapidly undergoes nucleophilic attack on the ester carbonyl and chopped the long polymer chains into oligomeric units via both inter or intrachain scissoring in less than 2 h. Thus, the self-immolative PAEs is uncontrollable under physiological pH; thus, they are not useful for drug delivery *in vitro* and under blood circulation *in vivo*. This emphasized that new synthetic strategies are essential to exploit the unique self-immolation characteristics of PAEs for drug delivery applications that require stable polymer-drug formulation at neutral pH. Recently, we have reported an elegant zwitterionic triblock copolymer strategy to stabilize the unstable self-immolate macromolecular chains at neutral pH via columbic interactions at the nanoconfinement and enable their drug delivery both in vitro and in vivo.[1] Biodegradable polycaprolactone (PCL) platform was chosen to build the triblock architectures having appropriate hydrophobic and anionic-cum-hydrophilic blocks along with cationic PAEs that brought excellent stability at neutral pH=7.4 in PBS, FBS, cell culture, blood plasma, non-hemolytic against RBCs and non-toxic to cells up to 100 □g/mL. The idea of combining enzyme-biodegradable zwitterionic triblock design to stabilize the unstable self-immolative cationic PEAs and selectively biodegrade the resultant nano-vector at the intracellular compartment is rarely reported in the literature. At neutral pH, the triblock zwitterionic nanovector experience Coulombic interaction between the carboxylic substituted anionic PCL and cationic PAE backbone that avert the de-protonation and stabilized the PAE chains. The zwitterionic polymer exhibited excellent encapsulation capabilities towards anticancer drug doxorubicin and tissue penetrable near infrared IR-780 biomarker to study their delivering capabilities in vitro and in vivo. *In-vitro* live cell real-time confocal microscopic studies revealed that the zwitterionic polymer-drug formulations was stable at the extracellular level and readily get internalized to undergo enzymatic-biodegradation in the endo-lysosomal compartments to deliver the payload. In this process, both the self-immolation of PAEs (in cytosol) and biodegradation of PCL occurred concurrently; thus, enabled digestions of entire polymer matrix intracellularly. *In-vivo* live animal IVIS bioimaging[2-3] established that the zwitterionic polymer platform was efficient in stabilizing the formulations under blood circulation for nearly 72 h and the biodistribution quantification of harvested tissues showed the accumulation of polymer nanoparticles predominantly in excretory organs.

Keywords: Self-immolative polymers, poly(amino-ester)s, Polycaprolactones, Drug Delivery, and Zwitterions

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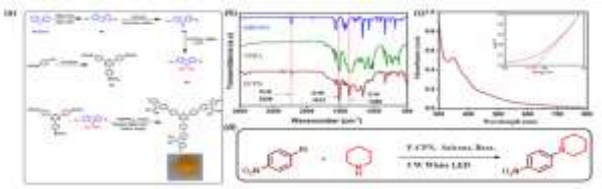
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Visible light-driven C–N cross-coupling reactions catalysed by a conjugated polymer network

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The development of sustainable photocatalysts for carbon-nitrogen (C-N) bond formation is gaining importance in modern organic synthesis.[1] Conjugated polymer networks (CPNs) have emerged as attractive photocatalysts owing to their structural diversity, tunable electronic properties, and high stability.[2] Herein, we report a fluorene-triazine-based CPN (FCPN) synthesized by Suzuki polycondensation [Figure 1(a)] that undergoes in situ Pd doping polymerization, enabling visible-light-driven metallaphotocatalysis. Spectroscopic [Figure 1(b)] and microscopic studies confirmed the polymer's structure, amorphous morphology, and uniform Pd(0) nanocluster (<10nm). The material exhibited a band gap of 2.4 eV [Figure 1(c)], moderate surface area (63.05 m^2 g^{-1}), and favorable HOMO/LUMO levels, ensuring strong charge separation and suppressed exciton recombination. Under white LED irradiation, having intensity 0.05 W cm^{-2} and power 3 watts, the FCPN catalyzed C-N cross-coupling between aryl halides and amines, affording high yields (95-82%) with 5 wt% catalyst loading [Figure 1(d)]. The protocol tolerated aliphatic, aromatic, and heteroaromatic substrates with functional groups such as nitro, cyano, and methoxy. Gram-scale synthesis of 4-(4-nitrophenyl)morpholine, 4-phenylmorpholine, and N-benzylpyridine-2-amine further demonstrated its practical utility. Mechanistic investigation showed that photogenerated charge carriers, in synergy with Pd sites, mediate reductive cleavage of activity, giving a turnover frequency of 1515.46 h^{-1}. This study highlights a simple, recyclable, and energy-efficient polymer photocatalyst for C-N couplings, offering a green alternative to conventional systems.



Figures 1- (a) Total synthetic scheme for the preparation of FCPN, (b) FTIR analysis, (c) UV-vis spectra of FCPN, (d) Schematic illustration of C-N cross-coupling reaction catalyzed by FCPN

Keywords: Conjugated polymer networks, Photocatalysis, C–N cross-coupling, Visible light catalysis, Porous organic polymers.

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Synthesis and study of some properties of bulk and thin film of amphiphilic homopolymers having 'Y' type pendant groups with varying alkyl side-chain length

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A series of amphiphilic poly[*N*-alkyl-*N*-(3-(isopropylamino)-3-oxopropyl)acrylamide] (polyMn) homopolymers having 'Y' type pendant group with varying alkyl chain length (n = 3–18) have been synthesized *via* reversible addition–fragmentation chain transfer (RAFT) polymerization using 1-phenylethyl phenyl dithioacetate (PEPD) as the RAFT agent. These polymers are characterized by ^{1}H NMR, gel permeation chromatography (GPC), differential scanning calorimetry (DSC) and powder X-ray diffraction (PXRD) studies. Unimodal GPC chromatograms have been observed for all polymers. Interestingly, DSC study has revealed the presence of both the endothermic glass transition temperature (T_g) and exothermic crystallization temperature (T_c). PXRD study revealed the observation of three types of broad peaks at $2\theta \approx 19.35°$ (d = 4.5 Å), ~3.5° (d = 25.2 Å) as well as also at ~11.7° (d = 7.56 Å), suggesting the presence of both amorphous and nanophase separated microstructures. Small angle X-ray scattering (SAXS), Fourier transform infra-red (FT-IR) spectroscopy, and atomic force microscopy (AFM) studies of their thermally and water annealed thin films have clearly revealed the nanophase separation and lamellar ordering behaviours. Results of these will be presented here.

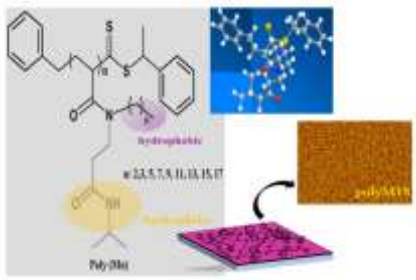


Figure: AFM image of polyM18 thin film.

Keywords: amphiphilic homopolymers, thin film, scattering studies, morphology study, nanophase separation.

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Synthetic Strategy to β-Sheet Polypeptides and Their Block Copolymers for Drug Delivery

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Synthetic polypeptides are continued to be one of the most challenging area for chemist to mimic the properties of the natural proteins to impart artificial intelligence in macromolecular systems for both fundamental understanding and technology development. Natural proteins have balanced architecture-control by cleverly choosing the amino acid sequences and lengths to manipulate *α-helical* and *β-sheet* secondary structures for precise globular self-assembly to carry out biological action under physiological conditions. The excellent solubility of the α-helical polypeptides enabled the synthesis of their block copolymer for diverse biomedical applications and this has been extensively reviewed. On the contrary, L-amino acid bioresources that promote *β-Sheet secondary* structures are one of the most difficult system to be handle by synthetic polymer chemist. This restriction has associated with the uncontrollable precipitation of the *β-Sheet* polypeptide chains in their synthesis. The heterogenous polymerization was found to be further responsible for the "non-living" nature with dead propagation chains which turned to be inefficient for making block copolymer architectures. As the consequence, synthetic β-sheet polypeptides and their block copolymer macromolecular architectures are still unexplored in the literature. As a result, mimicking the natural protein-like assemblies constituted by both *α-helical* and *β-sheet* contents in synthetic polypeptide is far from reality. To address this problem, we have designed and developed steric-hindrance assisted ring opening polymerization (SHAROP) synthetic strategy to access the high molecular weight *β-sheet polypeptides from* promoting *β-sheet L*-amino acid bioresources *L*-serine, *L*-cysteine and *L-tyrosine.*[1] In this process, a tert-butyl benzyl or tert-butyl benzoate bulky handle is introduced as structure directing-cum-solubilizing unit to drive the ROP process with excellent living polymerization kinetics. The propagating polymer chains have adopted α-helical conformation to grow in homogeneous reaction medium to yield soluble polymers for NMR and SEC analysis. Post-polymerization de-protection of the butyl unit has restored the *β-sheet polypeptides* having repeating units up to 200-300 units.[2] The SHAROP process was expanded to block copolymer technology with *L*-glutamate and *L*-lysine system to produce anionic or cationic *β-sheet core-shell* polypeptide architectures. The newly developed β-sheet core shells were found to be non-toxic to mammalian cell lines and opened new avenues for the unexplored β-sheet based block copolymers for long-term impact both in material and biomedical applications. The new process reported here opens up new platform for building high molecular weight β-sheet polypeptides by reversible conformation transition strategy and also creates new avenue to explore diverse block copolymer architectures that have been distant dream so far. Preliminary in-vitro and in-vivo investigations have postulated that these charged *β-sheet nano-assemblies* are potential candidates as cationic antimicrobial agents and anionic nanocarriers for anticancer drug delivery in cancer research.

Keywords: Polypeptides, Ring-opening polymerization, β-Sheets, Block copolymers, and Drug Delivery.

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Fibrous polyurethane-silica composite coating on leather and textiles: achieving superhydrophobicity

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Superhydrophobic coatings[1] are crucial for developing durable water-repellent materials[2,3]. Substrates such as glass, textiles, and leather, although widely used in daily applications, are intrinsically hydrophilic due to functional groups (–NH_2, –COOH, –OH), which hinder water repellency. To overcome this limitation, polymer nanocomposites have emerged as effective surface coatings. Among them, polyurethanes are particularly attractive because of their tunable urethane moieties, physicochemical versatility, and cost-effectiveness. Here, we report polyurethane/functionalized silica nanoparticle nanocomposites[4] as efficient superhydrophobic coatings.

For practical use on leather and textiles, two key aspects must be ensured: (i) uniform coating and (ii) preservation of water-vapor permeability by avoiding pore blockage[5]. Deposition of the nanocomposite in fibrous form via a spray technique addresses both requirements, offering clear advantages over continuous film deposition. Using this approach, leather surfaces exhibited water contact angles above 150°, significant abrasion resistance, and high water-vapor permeability. Notably, the coatings retained superhydrophobicity even after 30 min of continuous water flow (100 mL min^{-1}), attributed to their fibrous morphology. These findings highlight a scalable, fluorine-free strategy for designing versatile superhydrophobic coatings that preserve the functional properties of the underlying substrates.

Keywords: Fibrous Polyurethane, functionalised SiO_2, Superhydrophobicity, self-cleaning, breathable leather and fabric.

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Strategic Surface Engineering of a Colloidal nanoparticles as Platform for design of bespoke polymer materials for targeted applications

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In this work, we report the development of a versatile hyperbranched polymer platform synthesized via Aza-Michael addition reaction between N,N′-methylenebisacrylamide (MBA) and dialkylamine. This common precursor scaffold was further diversified to generate two functional polymeric systems with distinct properties and applications.

In the first pathway, the obtained hyperbranched nanogel was quenched with N-isopropylacrylamide (NIPAM) to afford a microgel, as previously reported by our group.[1] The microgel was further functionalized with mannosamine via Aza-Michael addition reaction to introduce bioactive carbohydrate moieties. The resulting mannose-functionalized microgel exhibited dual responsiveness (temperature and pH) with a volume phase transition temperature (VPTT) of 37.4 °C. Notably, this system selectively interacts with Concanavalin A (Con A) via multivalent lectin–carbohydrate binding. Fluorescence quenching studies revealed a rapid response time of ~8 minutes with a detection limit of 15 nM and a high binding constant of 3.77×10^6 M^{-1}. The fluorescence response of the sensor system showed high sensitivity and selectivity toward Con A, demonstrating its potential in bio-sensing applications.

In the second pathway, the initial hyperbranched nanogel formed via Aza-Michael addition reaction of diacrylate and a diamine, was reacted in situ with an endo-template (piperazine), yielding a crosslinked porous polymer network. The resulting gel was lyophilized to obtain a mesoporous polymer with a surface area of 143 m^2/g. Comparative studies using ethylenediamine and a template-free system showed that the piperazine-templated gel exhibited the better surface area, confirming the crucial role of the endo-template.[2] The lyophilized piperazine-based polymer showed excellent structural stability and was further evaluated for iodine adsorption. Notably, it demonstrated extremely fast uptake kinetics in batch mode, reaching saturation within 1 minute. The polymer also displayed impressive adsorption capacities (8.5 g/g in aqueous iodine and 12.4 g/g in the vapor phase), and remained highly effective in column-mode experiments and with real water samples, indicating strong practical promise for environmental remediation.

This dual-functional platform demonstrates how a simple synthetic strategy can be tuned to produce materials suited for both biological sensing and environmental remediation, highlighting its broad applicability in smart materials research.

Keywords: Poly(aminoamide), Stimuli responsive microgel, Lectin Binding, Mesoporous Polymer, Iodine Adsorption.

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Synthesis and Fabrication of Poly(vinylidene fluoride) Based Graft Copolymeric Membranes for Immobilized Metal Ion Chromatography Applications

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Rapid development of biotechnology and therapeutic utility of proteins requires their fast and large scale production preferably their downstream preparation from cell culture media. Affinity chromatography has cover up as an acceptable technique in this purpose. Immobilized metal ion based affinity chromatography (IMAC) has been a frontline contender amongst various affinity chromatographic techniques.1 The advantages of IMAC over other affinity chromatographic techniques are in respect of ligand stability, high protein loading efficiency, mild elution conditions, easier regeneration and of course low cost. In this regards, Poly(vinylidine fluoride) (PVDF) offers excellent membrane forming ability along with chemical inertness. However the major difficulty in using PVDF based membranes for protein immobilization/originates from hydrophobicity of PVDF surface leading to significant protein/bio molecule resulting in pore clogging. This problem may be alleviated by the attachment of hydrophobic moieties or polymeric chains on the PVDF backbone. However, there is a considerable debate over the mechanism particularly the initiation step by the cleavage of notoriously strong (C-F) bond which has already been explored, investigated and demonstrated from exhaustive XPS analysis that initiation possibly occurred following a "Halogen exchange" mechanism.2 Thus attachment of customized moieties in significant extent capable of exerting specific interactions with the molecules present in the bio analyte should be extremely difficult. This might account for very little number of reports for the application of PVDF in affinity chromatography or mare precisely to IMAC. In a multistep protocol Suen et al.3 reported that the attachment of metal chelating ligand through spacer moiety with the commercially available micro porous PVDF membrane. In order to ensure the presence of greater proportion of metal binding ligands over the PVDF membrane surface, we have carried out grafting of PVDF chains by random copolymerization of glycidyl methacrylate with hydrophilic PEGMA or DEGMEM. The polymers attached PVDF-g-Poly(GMA-r-PEGMA) (PVGPE) and PVDF-g-poly(GMA-r-DEGMEM) (PVGD) were undergoes 'Phase Inversion' to get corresponding micro pores membranes. The use of reactive epoxy functional groups of PGMA to incorporate desired affinity moieties is well reported in the literature. On the other hand, hydrophilic polymer chains were attached to import hydrophilicity and Centrifouling characters to the membranes. The fabricated PVGPE and PVGD films were then treated with aqueous IDA solution where alkaline pH followed by aqueous CuSO4 solution for loading of particularly Cu+2 ions on the membrane surface and within the pores. The structure and morphology along with the antifouling characteristics of the membranes were thoroughly characterized by several spectroscopic (1H-NMR, XRD, XPS, FTIR, UV-Vis and PL) and electron microscopic (SEM) techniques. An appreciably high protein immobilization ~0.75 mg/cm2 for BSA has been recorded.

Keywords: IMAC, Halogen exchange, Antifouling, Protein immobilization, Phase Inversion.

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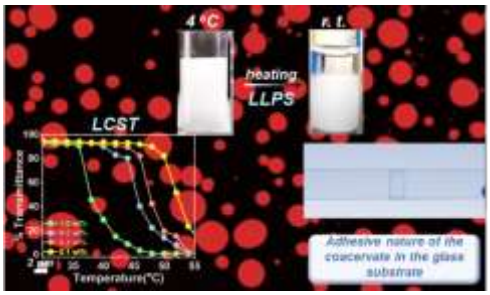
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Self-Coacervation of a Nonionic Thermoresponsive Homopolymer for Potential Applications

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Living systems accomplish a variety of multifaceted functions - like metabolic bustle, reproduction, adaptation, and compartmentalization. Among these, compartmentalisation is crucial because it provides limited compartments for critical metabolic reactions while protecting sensitive internal components from the external environment. This idea has inspired researchers to investigate membrane-less compartments like coacervates and protocells in order to comprehend rudimentary cell-like systems and create useful biomaterials. In this perspective, nonionic, single-component coacervates showcased diverse advantages over orthodox charge-driven complex coacervate systems. Their improved constancy against environmental oscillations, including pH and ionic strength, makes them specifically attractive for applications in dynamic or physiological circumstances. Here, we extant our finding that a pyroglutamic acid–based LCST-type thermoresponsive homopolymer undergoes liquid–liquid phase separation depending on temperature stimuli, leading to the formation of nonionic coacervate droplets. By tuning the cloud point temperature (T_{cp}), the phase behavior can be controlled, enabling efficient encapsulation of a wide range of cargo molecules. We demonstrate successful loading of large biomolecules such as proteins, as well as small molecules including the anticancer drug doxorubicin and the fluorescent probe Nile Red. This tunable coacervate system provides a simple yet versatile strategy for constructing functional compartments with broad utility. Beyond their promise as delivery vehicles, the phase-separated assemblies also exhibit adhesive properties, highlighting their potential in drug delivery, biomedical coatings, and other advanced therapeutic applications.



Keywords: Liquid-liquid phase separation, Coacervate, LCST, Adhesives.

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A Multifaceted Methodology for Functional Polythioesters by Condensation Polymerization Exploiting Activated-Ester Chemistry

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Sulfur-containing polymers are gaining interest due to their unique properties, such as metal coordination, high refractive indices, self-healing behaviour, and the ability to form robust self-assembled monolayers (SAMs) with gold nanoparticles.[1] Polythioesters, in particular, stand out from their polyester counterparts due to their high refractive index, enhanced crystallinity, and improved depolymerizability, making them promising for dynamic, recyclable, and degradable materials. In this study, we report the one-pot synthesis of polythioesters utilizing an activated pentafluorophenyl diester of adipic acid (A1) in combination with a range of structurally distinct dithiols, viz., hexanedithiol, propanedithiol, and 3,6-Dioxa-1,8-octanedithiol under mild conditions (75°C) following our previously reported methodology on polyester synthesis employing activated ester chemistry.[2,3]- After successful optimization of the requisite reaction conditions, we introduced functional diversity by incorporating distinct end groups such as aromatic pyrene moiety or hydrophilic PEG chain at the polymer chain end. This was achieved by following two approaches: 1) by taking monofunctional thiols as “impurities" during the polymerization reaction and 2) by generating thiol-capped telechelic polythioesters via a "stoichiometric imbalance" strategy and their subsequent post-modification by thiol–ene based Michael addition. Furthermore, we conducted an in-depth analysis of the thermal characteristics exhibited by the synthesized polythioesters, revealing their high thermal stability and influence of their molecular structure on both crystallization property and melting temperatures. Additionally, we examined the enzymatic degradation process of these polythioesters under aqueous conditions by cysteine-mediated native chemical ligation following a biocompatible pathway.[4] In this presentation, I will discuss different facets of our newly established methodology for structurally diverse functional and degradable polythioester with near-quantitative conversion employing activated ester chemistry.

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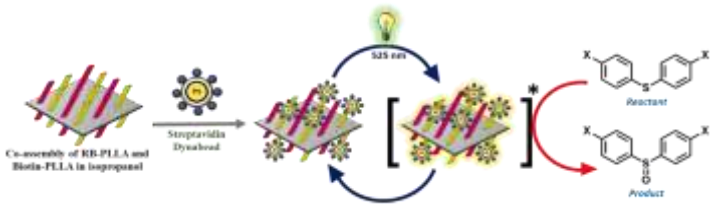
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Harnessing Crystallization-Driven Two-Dimensional Polymeric Assemblies for Efficient and Reusable Photocatalysis

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Photocatalyzed reactions, though offering a sustainable and energy-efficient pathway to innovation, still remains as a challenge due to short-lived triplet state of the photosensitizing dyes and due to difficulty in regaining the catalyst. Typically, these dyes in their triplet state undergo non-radiative decay, leading to short triplet lifetimes and reduced efficiency. However, embedding the dyes into polymeric systems is expected to enhance the triplet state lifetime by stabilizing the excited states and reducing non-radiative decay pathways in rigid environment of polymeric matrix restricting the molecular vibrations and rotations, reducing energy loss and extending the triplet lifetime.[1] We aimed to investigate photocatalysis using Rose Bengal initiated poly(L-lactide) (RB-PLLA) for the model oxidation reaction of sulfide to their respective sulfoxide. RB-PLLA in isopropanol undergoes crystallization-driven self-assembly (CDSA),[2] which yielded well-defined 2D diamond-shaped platelets, surface-decorated with the sensitizer.[3],[4] These were then used for photocatalytic aerial oxidation of sulfide to sulfone. These 2D nanoplatelets showed superior photocatalytic performance compared to the free RB sensitizer. For catalyst recovery and reuse, RB-PLLA was co-crystallized with Biotin-PLLA, enabling decoration of 2D surface with biotin (scheme 1) which exhibits strong binding for streptavidin. [5] Using streptavidin-coated magnetic beads, the catalyst was successfully extracted and reused for multiple cycles. The study highlights a novel approach to grafting and stabilizing photocatalysts on 2D surfaces and enabling their recyclability through a facile polymer chain crystallization-mediated self-assembly strategy [6]. These aspects of photocatalytic design integrated into crystallizable biopolymers for recyclable catalysis, will be discussed in detail during the poster presentation.



Scheme 1: Illustration showing recyclable photocatalytic system functionalized with photosensitizers.

Keywords: Crystallization-driven self-assembly (CDSA), Photocatalysis, poly-L-Lactic acid (PLLA), Rose Bengal.

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White-Light Emitting Redox-Active Two-Dimensional Assembly of a Phenothiazine Derivative via Crystallization-Driven Self-Assembly of Poly(L-lactide)

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Crystallization-driven self-assembly (CDSA) of amphiphilic crystallizable block copolymers represents a powerful tool for constructing precision nanostructures with uniform shapes and dimensions. To date, major efforts have been towards achieving structural control employing living-CDSA. Previously, our group explored precise diamond-shaped 2D platelets in isopropanol under suitable condition, causing the terminally attached chromophores to assemble into 2D array on the platelet surface by either dipole-dipole interactions for dipolar chromophores: naphthalene monoimide (NMI) and merocyanine (MC) or aromatic stacking for nonpolar pyrene (PY).[1,2] Now we are diversifying the chromophoric effect and have introduced a highly emissive, redox-active dipolar phenothiazine (PTZ) dye, to enable colloidal stability to the 2D platelets.[3] Multi-layered lozenge-shaped 2D nanoplatelets were formed by CDSA of PTZ-P1 in 20% iPrOH/water medium. The PTZ (orange-emitting) on the surface of the PLLA assembly can be selectively oxidized to form phenothiazine sulfoxide[4] (OPTZ, cyan-emitting) in presence of NaClO without compromising the intrinsic 2D morphology. The photoluminescent color of the 2D PLLA structures can be tailored by controlling the extent of OPTZ and PTZ in the assemblies, making it possible to create white-light (WL) emission with CIE coordinates (0.31, 0.36) depending upon the analyte concentration. PTZ-P1 was co-assembled with separately synthesized OPTZ-P1 for better control over surface emission properties and in a specific ratio yielded stable WL via FRET with 32% efficiency. In contrast, physical mixing of the preformed cyan- and orange-emitting nanoplatelets (2:1) produced a WL emitting system through simple additive color mixing, without FRET; as a result, the individual platelets could retain their original color.

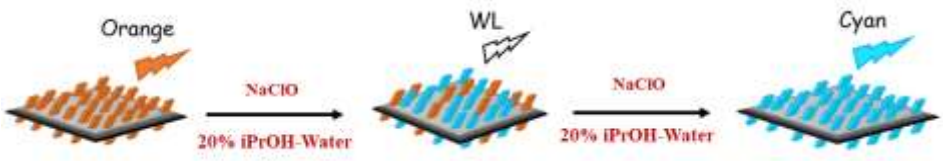


Figure 1. Schematic representation of NaClO-triggered transient white-light-emitting 2D.

Keywords: Crystallization driven self-assembly (CDSA), 2D platelets, Redox responsive, White-light emission.

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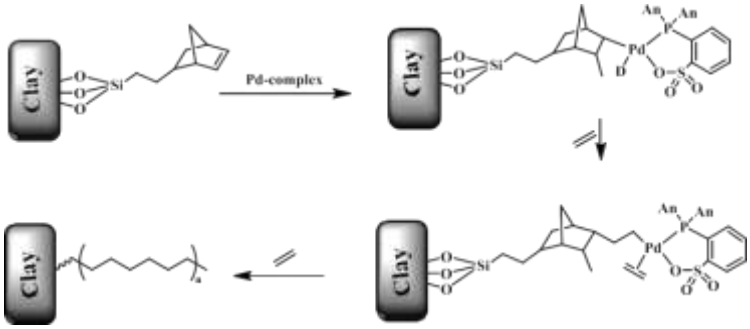
5.

Design of a Heterogeneous Phosphinobenzenesulfonate-Pd Catalyst for Ethylene Insertion Polymerization

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Phosphinobenzensulfonate-Pd complex (POS-Pd) is one of the widely used catalyst systems for ethylene polymerization, and can effectively be utilized to copolymerize ethylene with functional olefins, as it increases hydrophilicity and adhesive properties. However, this catalyst had never supported on a heterogeneous substrate before and was not used for the preparation of clay-tethered polyethylene. Here, we presented a novel polyethylene nanocomposite with sheet-like silsesquioxanes that is covalently grafted, showing excellent adhesion to different substrates such as metal and glass surfaces. This structure was formed by undergoing Pd-ACN complexations with a norbornene-ended, layered Mg-silsesquioxane. The clay-supported POS- Pd catalyst was further confirmed by traditional ^{31}P NMR spectroscopy, ICP analysis (10 wt% palladium) and CP-MAS NMR. This catalyst was further tested in ethylene polymerization at high pressure, and the polyethylene product showed all characteristics properties. This methodology offers a variety of possible routes to improve the adhesive operability in polyethylene with clay introduction by the design of a new catalyst formulation, showing how their performance can be extended on-surface functionalized polymer.



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Microwave Absorbing Fluorescent Copolymer with Enhanced Anti-Counterfeiting Security Features

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Counterfeiting is a significant issue affecting various sectors, including banking, insurance, pharmaceuticals, and commercial goods. A combination of security elements creates a multi-layered protection for counterfeiting prevention, ensuring diverse authentication against fraud and unauthorized duplication.[1] To design microwave-absorbing polymers with optical transparency and fluorescence, methyl methacrylate (MMA) was copolymerized using reversible addition-fragmentation chain transfer (RAFT)[2] polymerization with 2-(dimethylamino)ethyl methacrylate (DMAEMA) and pyrene methacrylate (PyMA). The amine moieties from the DMAEMA repeating units in the copolymer were ionized at room temperature by treating with hydrochloric acid (HCl) or trifluoroacetic acid (TFA), resulting in copolymer salts with an ion-pair complex. Optical transparency, fluorescent properties, and ionic conductivity of the copolymer salts with chloride (Cl^-)/trifluoroacetate (TFA^-) counter anions and pyrene moieties were studied in detail. Optically transparent fluorescent copolymers with partially mobile Cl^- counter anions witnessed strong microwave absorption due to multiple reflections from structural and physical anisotropies. This study highlights a strategy for designing a material that combines multiple features like microwave absorption,[3] optical transparency, and characteristic fluorescence emission,[4] within a single material system, a key area of research in the security[5] and communication industries.



Figure 1. Schematic of multifunctional polymer coating showing microwave absorption, fluorescence, and anti-counterfeiting potential.

Keywords: Methyl methacrylate (MMA), RAFT polymerization, Microwave-absorbing materials, Optical transparency, Anti-counterfeiting technology.

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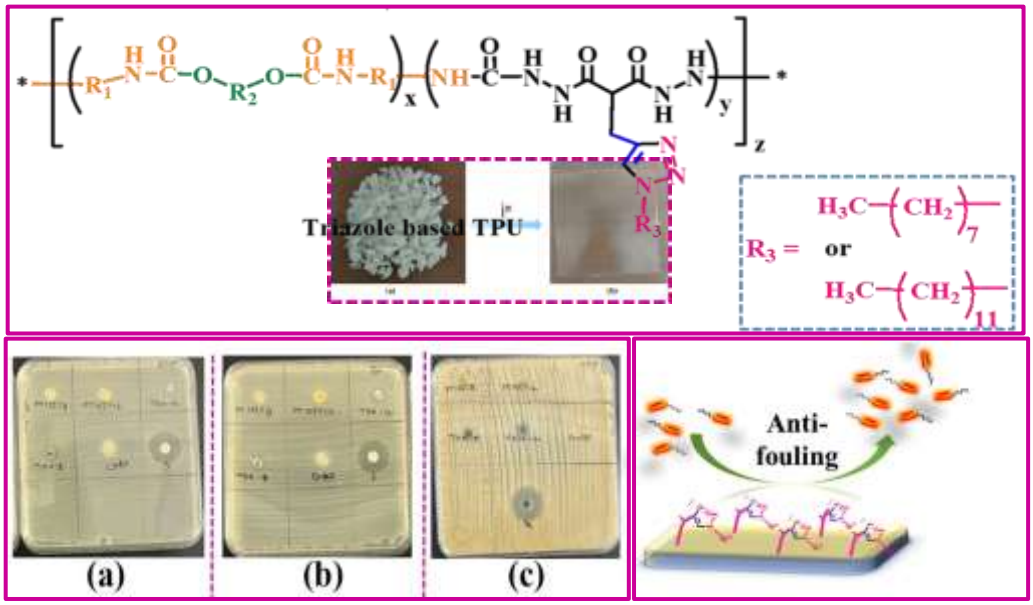
Thermoplastic Polyurethanes carrying Triazole moieties – studies on the properties and antimicrobial activity

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Thermoplastic polyurethanes (TPUs) stand out for their remarkable versatility, tunable properties, and broad applications in biomedical, automotive and industrial fields. However, polyurethanes (PUs), by their nature, tend to allow bacteria to adhere to their surfaces, which can lead to bacterial growth and biofilm formation. Because of this drawback, researchers have been working to modify PU materials in such a way that they inherently resist bacterial attachment and growth, rather than relying on external coatings or treatments. Covalent incorporation of quaternary ammonium compounds (QAC), pyridinium (Py) and triazole (Tz) moieties addressed the issues related to processability, long-term stability, mechanistic clarity, and translational feasibility.

This study reports the design and development of thermoplastic polyurethanes (TPUs) incorporating pendant 1,2,3-triazole (Tz) moieties. The triazole functionality was introduced via a Cu (II)-catalyzed azide-alkyne click chemistry approach which was converted into triazole based dihydrazide. TPUs were synthesised by reacting polyol, diisocyanate and the dihydrazide which were compression molded into films. Antimicrobial evaluations against *Escherichia coli* (Gram-negative), *Staphylococcus aureus* (Gram-positive), and *Candida albicans* (fungal strain) demonstrated that the triazole-functionalized TPUs effectively inhibited microbial growth and adhesion, indicating antifouling potential.



Keywords: thermoplastic polyurethanes, antimicrobial, triazole, alkyne-azide click reaction.

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Self-Assembly of Block Copolymer Prodrugs in Pure Aqueous Medium Creating Unique Bicontinuous Nanoparticles for Potential Cancer Treatment

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Bicontinuously structured polymeric nanoparticles (BSPNPS) are rarely explored owing to their complex designing of precursor copolymers and multistep synthetic procedures.[1] Moreover, the structure formation required either mixed solvent or nanoprecipitation, making them less suited for complex drug delivery.[2] In counter, our group synthesized a very simple redox responsive diblock copolymer (P1) which was further utilized to prepare doxorubicin(DOX) containing pH-labile prodrug (P2).[3] Remarkably, both P1 and P2 self-assembled in pure aqueous medium while adopting the rare bicontinuous morphology, which in our knowledge was not reported previously. The morphology of the nanoparticles formed was characterized by HRTEM and SAXS measurements. The unique structure of naoparticles allowed simultaneous loading of both hydrophilic as well as hydrophobic cargos, thus providing a potential direction towards combination or synergistic therapy. Stimuli-responsiveness of the BSPNPs further helped us in selective drug release under cancer cell environment (pH 5.0 + 10 mM GSH), and the corresponding morphological changes of the nanoparticles were monitored by different spectroscopic method. *In vitro* cellular studies asserted the safe nature of the nanoparticles against noncancerous cells (HEK293T) compared to free DOX. In contrary, the nanoparticles displayed higher drug-induced cytotoxicity against cancer cells (MCF-7) than free DOX, thereby evincing them as promising drug delivery systems.

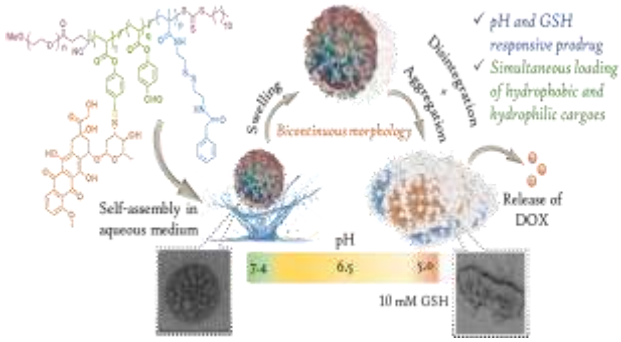


Figure 1: Graphical representation of the work

Keywords: Bicontinuous, Diblock copolymer, Cytotoxicity, Prodrug

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Probing The Factors and Reasons Behind Gel Formation of Ionic Liquid Based Homo Polymers

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Polymeric gels are semi solid materials which have potential to hold fluid within its 3D porous cross-linked networks. Based on the nature of polymer chain, types of solvent embedded inside it, these materials further categorized into organogel and hydrogel.[1] These gels can be extensively used in soil irrigation, in-vivo drug delivery systems, making wound healing/ self-healing materials, in extraction of toxic metal ions and dye absorption from industrial effluents.[1–3] Based on gelation mechanism, gels can be classified as Chemical gels and physical gels. In chemically cross-linked gels, polymer chains intertwined by strong covalent interactions using cross-linking agents which are irreversible with respect to external stimuli by addition of excess solvent, changing pH, temperature. In physically cross-linked gels formation of crystallite regions, supramolecular, electrostatic, hydrophobic or hydrophilic interactions triggers gel formation within polymer chains which are reversible in nature. Among variety types of gel, homopolymer gels are more preferrable because of its structural uniformity, easy reproducibility, possess specific mechanical strength, stability and rheological characteristics.[4,5] Recently, we found some anomalous observations in carrying out polymerization using our ionic liquid based monomers bearing different pendant alkyl groups. Some of these homo-polymers showed characteristics of super absorbent hydrogel without addition of any external additives. In this proceeding event, we present factors and reasons behind gel formation of some of these IL based homopolymers.

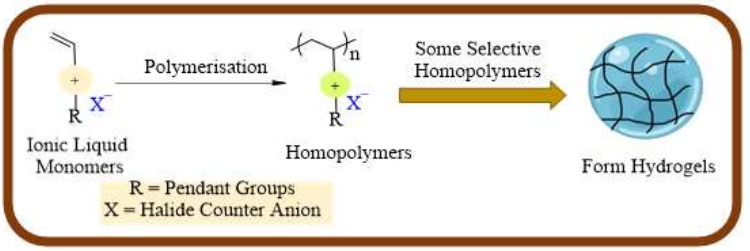


Figure 1. Diagrammatic representation of homopolymer hydrogel formation.

Keywords*:* Poly (ionic liquids), Gelation, Hydrogels

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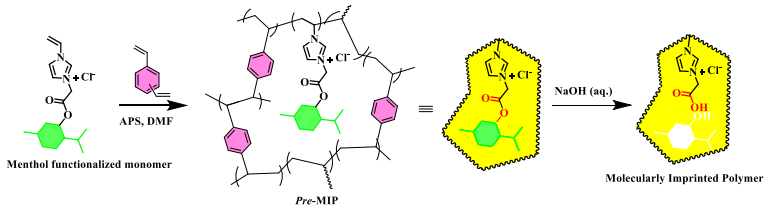
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Molecularly Imprinted Polymers of Menthol: Synthesis and Separation Abilities

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Derivatives of natural polymers, such as cellulose and amylose, are most commonly used as chiral separation phase (CSPs) materials in high-performance liquid chromatography for chiral separation.[1] Synthetic chiral helical polymers have recently given promising chiral resolution efficiency and have been utilized as both CSPs[2] and chiral resolving agents. However, the molecularly imprinted polymers (MIPs), distinct materials that resemble biological receptors in structure and function, have not yet been properly utilized as CSPs, though the conceptualization has long been reported.[3] The template specificity of these materials has long been sought for chiral resolution of the enantiomers of pharmaceuticals, pesticides, steroids, fragrances, food additives, etc. The selection of functional monomer, crosslinker, free radical initiator, and porogenic solvent depends on the functionality of the template and the approach used in synthesis.Here, the semi-covalent approach in which the template binds to the monomer covalently before polymerization and noncovalently during rebinding was chosen, as menthol has structural similarity with steroids.[4] At first, menthyl chloroacetate was synthesized from menthol and chloroacetyl chloride through nucleophilic substitution. This was followed by quaternization with 1-vinylimidazole to get the desired menthol-based monomer. Divinylbenzene as crosslinker, ammonium persulfate as free radical initiator, and dimethyl formamide as porogenic solvent were used in the free radical polymerization of menthol-based monomer. Saponification and subsequent dilute acid treatment led to the formation of the imprinted polymers. Our initial studies are focused on the separation of menthol from camphor using those polymer materials through static batch binding experiments. The results from the gas chromatographic analyses reveal its good separation efficiency. Currently, we are studying its (Menthol-based MIP) chiral separation efficiency.



Scheme 1. Synthesis of the molecularly imprinted polymers of menthol.

Keywords: Chiral resolution, molecularly imprinted polymers, semi-covalent approach

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Advances in Waterborne Polyurethane Coatings for Corrosion Resistance: Design Strategies, Mechanisms, and Sustainable Developments

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Waterborne polyurethane (WPU) coatings have gained significant attention as environmentally benign alternatives to conventional solvent-borne coatings for corrosion protection due to their low volatile organic compound (VOC) emissions, tunable structure, and adhesion to metallic substrates. The intrinsic flexibility and chemical versatility of polyurethane chemistry allow for the precise control of hydrophilicity, crosslinking density, and mechanical integrity, which are essential for achieving superior barrier properties. However, the presence of hydrophilic segments in conventional WPUs often limits their long-term corrosion resistance. To address this, recent research has focused on incorporating functional nanofillers—such as graphene oxide, silica, and ZnO—that improve tortuosity for ionic diffusion and enhance the coating's anticorrosive barrier. Additionally, silane coupling agents and hybrid organic–inorganic networks have been employed to improve interfacial adhesion and reduce water permeability. The development of self-healing and conductive WPU systems using redox-active oligomers and microcapsule-based strategies has further extended their service life and durability. Moreover, the shift toward sustainable materials, including bio-based polyols and internal emulsifiers derived from renewable feedstocks, has enabled the creation of DMPA-free, green WPU coatings with improved performance. This review discusses the current progress in molecular design, structure–property relationships, and corrosion protection mechanisms of WPU-based coatings, while highlighting future directions toward multifunctional, durable, and eco-friendly anticorrosive systems.

Keywords: Waterborne polyurethane, corrosion resistance, nanocomposite coating, barrier properties, eco-friendly materials.

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Polymer/Graphene Oxide Nanocomposite via Mini-Emulsion Polymerization

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In an aqueous polymer graphene oxide (GO) dispersion, the restacking and subsequent precipitation of GO sheets frequently result in spontaneous phase separation.[1,2] This has been a significant challenge, limiting the commercial production of aqueous polymer/GO-based paints and coatings.[3] In this study, we have synthesized a colloidal stable polymer-graphene oxide nanocomposite latex via mini-emulsion polymerization. In this case, lauryl methacrylate was copolymerized with a bio-derived monomer, isobornyl methacrylate, using radical polymerization implemented as mini-emulsion polymerization. The emulsion was characterized by Dynamic Light Scattering (DLS). The polymer-GO composite was characterized using Raman spectroscopy, X-ray Diffraction (XRD), and Fourier transform infrared spectroscopy (FTIR). The hydrophobicity of the nanocomposite films was assessed through contact angle (CA) measurement using a Goniometer. Overall, the results demonstrate a viable pathway for the commercial production of colloidally stable aqueous polymer-graphene oxide (GO) composite for application in paints and coatings.

Keywords: Graphene oxide, Polymer-graphene oxide nanocomposite, Mini-emulsion polymerization.

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Hydrophobically Modified Self-healable UV-resistant Smart Polymer/MOF Composite for Coating Application

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In recent years, self-healing materials have garnered significant scientific interest, specifically focusing on macromolecular chemistry to tailor functional polymers with desired healing properties. This study presents the development of a hydrophobic, self-healable, UV-resistant smart polymer/metal-organic framework (MOF) composite for coating applications. The copolymer of glycidyl methacrylate and lauryl methacrylate P(GMA-*co*-LMA) copolymer was prepared for its hydrophobicity, flexibility, self-cleaning, and heat-induced self-healing properties, while the MOF provided antimicrobial and anti-UV capabilities. By incorporating MOF into the copolymer, a significant enhancement in these functionalities is achieved, alongside increased surface roughness and improved water contact angle. The copolymer was characterized using ^{1}H- Nuclear Magnetic Resonance (^{1}H-NMR), Fourier-transform infrared (FTIR) spectroscopy, and Differential Scanning Calorimetry (DSC). Subsequently, the composite was analysed via FTIR, X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), UV-Vis spectroscopy, water contact angle measurements, and antimicrobial tests. This innovative composite paints a promising picture for multiple smart applications, particularly in sectors requiring advanced durability and protection, such as military textiles, passport covers, and other high-performance coatings. The facile synthesis method highlights the potential for scalable production of multifunctional fabrics, aligning with current industrial needs for smart, robust materials with environmental resistance and self-repair capabilities.

Keywords: Polymer/MOF, Self-healing, UV-resistant, Hydrophobic, Smart Coating.

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Surface Decontamination using Strippable Coating Material based on Acrylic Emulsion

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Radioactive materials have played a pivotal role in advancing human society, finding applications across diverse sectors[1]. However, the same properties that make radioactive materials so beneficial also pose significant hazards. The emission of ionizing radiation from radioactive materials is dangerous not only for humans but also for ecosystem[2]. Furthermore, improper handling, accidental release or long-term persistence of radionuclides in the environment result in contamination of different surfaces which may lead to further secondary contaminations through contact, resuspension into the air or absorption into porous materials. To address this issue, various physico-chemical decontamination techniques have been developed[3]. Among these, strippable coatings have emerged as a highly effective and user-friendly approach as these do not generate large volumes of secondary liquid waste, can be applied to a wide variety of substrates, offer simplicity of application and can cover irregular geometries and hard-to-reach areas [4]. In the present study, we report development i.e., synthesis, characterization and performance evaluation of a strippable coating material based on a water-based acrylic emulsion. Synthesis was accompanied by mixing of different additives, for their particular functional requirements, in the acrylic emulsion. Prepared material was comprehensively characterized to understand its important physico-chemical properties. Different techniques used for this purpose included pH meter, Rheometer, Turbiscan Stability Analyzer, Elcometer, FTIR, TGA, DSC, UTM and SEM. The surface decontamination efficiency of the prepared material was evaluated for three representative surfaces [viz. stainless steel (SS), polyvinyl chloride (PVC), and ceramic (CE)]. Mainly four different concentrations (0.005 M, 0.05 M, 0.5 M, and 5.0 M) of the contaminant were used to replicate different degrees of surface contamination. Cesium fluoride (CsF) was used as the contaminant that comprised of stable cesium isotope (^{133}Cs) as a surrogate for radioactive ^{137}Cs. It was demonstrated that the decontamination efficiency for different surfaces decreases with increasing surface contamination concentration and followed the order 98.0-100% (0.005 M) > 87.77–99.89% (0.05 M & 0.5 M) > 65.19-91.77% (5.0 M). Further, decontamination efficiency was also found to be depended on the smoothness of the surface where it followed the order CE > SS > PVC. These findings highlight the capability of the prepared material in effective surface decontamination under a wide range of contamination scenarios.

Keywords: Surface Contamination, Strippable Coating, Acrylic, Decontamination.

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Development of Reprocessable Hot-Melt Adhesive via Nucleophile-Mediated Ring-Opening Copolymerization of Benzoxazine and Elemental Sulfur

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Polybenzoxazine is a new class of high-performance phenolic thermosetting material prepared by the ring-opening polymerization of benzoxazine monomers without needing any external catalyst. They outshine conventional thermosets due to their unique properties, high thermal stability, low water absorption, no or less volatile release during curing, and low volume shrinkage with excellent dimensional stability. The permanent covalent crosslinks are responsible for the exciting properties of thermosets however, they hinder their reprocessability, generating huge waste which ends up segregated into landfill. Thus, a severe solution is the need of the hour to eradicate plastic pollution. The inclusion of dynamic bonds, for instance, sulfur-sulfur linkages into the polybenzoxazines networks, imparts reprocessability, repairability and recyclability to the material due to their dynamic nature at room temperature or under weak stimuli. In this work, a multifunctional benzoxazine monomer based on cardanol and 4-Aminophenyl disulfide was designed in order to accommodate polysulfide linkages into the network based on mechanism such as sulfur inclusion into disulfide linkages polysulfides incorporation via inverse vulcanization, Sulfur Radical Transfer and Coupling Reaction and Catalytic Opening of the Lateral Benzoxazine Rings by *Thiols*. Furthermore, the chemical, rheological and mechanical properties of the synthesized new age material were studied to obtain a fast-relaxing thermosetting polymer suitable to use as a reprocessable adhesive for metal plates.

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Novel Biodegradable Polymer-based Coating for Jute used in Food Grain Packaging

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Jute is one of the most widely used natural fibers for packaging food grains in India due to its biodegradability and cost-effectiveness. The Ministry of Textiles mandates that 100% of food grains shall be packed in jute packaging material. However, high porosity, moisture uptake, and poor barrier performance make it prone to deterioration and pest infestation, limiting its effectiveness in long-term storage[1]. To overcome these challenges, biodegradable polymeric coatings on jute have been explored to reduce post-harvest storage loss. In this study, polybutylene adipate terephthalate (PBAT), a biodegradable aliphatic–aromatic copolyester, was investigated as a novel coating for woven jute substrates. Polymer solutions of varying concentrations were used to examine the effect of polymer concentration on coating thickness, surface morphology, wettability, mechanical properties, and barrier properties. Optical microscopy of PBAT-coated jute confirmed the closure of inter-fiber gaps and surface smoothness increasing with coating thickness. Water absorption tests showed a significant reduction in water uptake (less than 100%) in comparison with uncoated jute for 24 hours. There is an increase in the water contact angle of coated jute, indicating enhanced hydrophobicity. The coating also offers moderate water vapor and oxygen permeability, which is beneficial for extending the shelf life of stored grains[2]. The mechanical properties of PBAT are known to be similar to low-density polyethylene (LDPE), which has been observed to resist insect pest penetration that causes damage to food grains[3]. These findings highlight the feasibility of the novel biodegradable polymer as a sustainable coating for natural fiber-based packaging, offering improved barrier, mechanical, and functional properties for long-term food grain storage.

Keywords: Biodegradable polymer, PBAT, Jute, Sustainable packaging.

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Development of Chitosan/Water Caltrop Pericarp Extract Composite Edible Film and Coating and its Application for Storability Enhancement of Strawberries at Ambient Storage

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This study focuses on developing and characterizing active and sustainable packaging films made from chitosan (CS), enriched with a novel bioactive extract sourced from water caltrop (Trapa bispinosa Roxb.) pericarp (WCPE). In this study, chitosan (1 % w/v) based biocomposite films were produced using varying concentrations of bioactive extracts (0,5,10,15 and 20 % w/w of CS) from water caltrop pericarp, obtained through ultrasound-assisted extraction. WCPE extract possess excellent antioxidant (89 ± 1.41 %), higher phenolics (120.48 ± 4.67 mg GAE g−1) and antimicrobial property. Similarly, developed biocomposite demonstrated superior UV barrier (OP600nm ~4.30), lower swelling (21.43 ± 2.61 %), lower moisture content (17.15 ± 1.82 %), minimum water vapor permeability (1.28 ± 0.06 g m−1 day−1 Pa−1 (×10−10)), excellent antioxidant capacity (60.41 ± 1.52 % for DPPH and 70.80 ± 2.36 % for ABTS), greater phenolics content (168 ± 4.16 mg GAE/100 g) and good antimicrobial property. Additionally, all formulated coating solutions demonstrated biocompatibility (>85 % cell viability) with BHK-21 fibroblast cells. Finally, the CS-WCPE20 solution was evaluated for its practical use as an edible coating to preserve strawberry, under storage conditions of 20 ± 5 °C and 75 ± 5 % relative humidity. Developed coating successfully preserved quality attribute such as lower weight loss (~17 %), higher texture (~2.18 N), optimum TSS (~8.44 % Brix), maximum antioxidant quality (~50 % DPPH scavenging activity) and higher color and visual attribute upto 8 days at ambient temperature. Thus, the optimized formulation demonstrates significant potential for use as an active and intelligent packaging solution, effectively extending the shelf life of fruits and vegetables.

Keywords:
Trapa bispinosa Roxb., Pericarp polyphenol, Active packaging, Postharvest preservation.

Polysilazane as a Transformative Crosslinker: Toward Sustainable, Multifunctional Coatings and Adhesives

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Replacing toxic diisocyanates offers a safer and more sustainable route to curing acrylics and polyurethanes. Polysilazane (PSZ), a silicon-based polymer that readily forms robust siloxane (Si–O–Si) networks, is employed here as a hybrid organic–inorganic crosslinker, combining effectively with functional acrylic and polyurethane systems to deliver multifunctional performance[1]. Crosslinking through a siloxane (Si–O–Si) network and low-energy Si–O backbonding imparts hydrophobicity, chemical–mechanical stability, and long-term performance under harsh weathering. Acrylic–PSZ coatings on metals exhibit strong adhesion (5B), high hardness (6H), and outstanding anti-corrosion behavior, with I_{corr} values of 1.6×10^{-7} A and resistance to higher oxide formation even after 15 days of salt solution immersion[2]. They also provide excellent iceophobicity, with a freezing delay time of ~590 s and rapid melting response near 5 °C. On bio-based substrates such as wood and cellulose, PSZ-crosslinked coatings generate glossy, low-energy surfaces with enhanced water repellence, self-cleaning ability, UV shielding, barrier protection, and mechanical reinforcement, achieving tensile strengths up to ~13 MPa alongside V-0 fire ratings and self-extinguishing behavior via coherent inorganic char layer. In adhesives, PSZ increases the glass transition temperature from 31 °C to 56 °C and delivers superior tensile shear strengths of 4.4 MPa on wood and 4.0 MPa on aluminum, surpassing diisocyanate-based systems[3]. Collectively, these results establish PSZ as a transformative crosslinker that unites organic flexibility with inorganic robustness, offering a universal, high-performance, and safer platform for coatings and adhesives across infrastructure, sustainable substrates, packaging, and advanced materials[4].

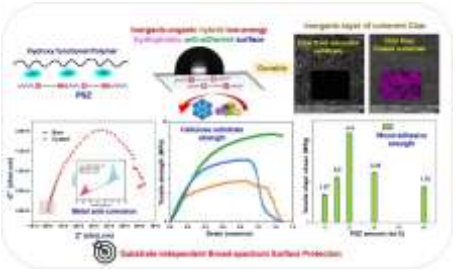


Figure 1: Polysilazane as a crosslinker for creating low-energy fast-curing substrate-independent coating and adhesive systems.

Keywords: Polysilazane, Hybrid Coating, functional coatings, packaging, functional adhesives.

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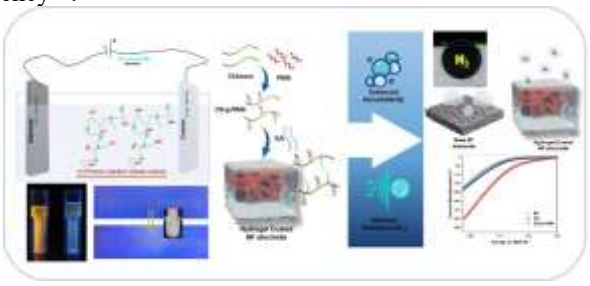
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Intelligent Coating Systems: From Corrosion Protection and Detection to Sustainable Hydrogen Evolution

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Developing multifunctional coatings that simultaneously protect, sense, and enable energy-relevant processes is critical for advancing infrastructure and green technologies. Here, we demonstrate an acrylic-based cathodic electrodeposition (CED) system in which positively charged polymer chains co-deposit fluorescent nitrogen-doped carbon dots (N-CDs) directly onto metal substrates serving as the cathode[1,2]. This process yields an ultrathin, strongly adherent coating with superior corrosion resistance, impedance values increase by four orders of magnitude compared to conventional acrylic coatings. Beyond protection, the intrinsic fluorescence quenching of N-CDs toward Al^{3+} is translated into a simplified corrosion detection device: a low-cost, pH-paper-like strip printed with N-CD ink that enables naked-eye identification of aluminum corrosion through a "turn-off" fluorescence response. During CED, hydrogen evolution naturally occurs at the cathode, linking electrode protection with green energy processes[3]. Inspired by this coupling, we engineered a fully bio-based superaerophobic hydrogel for the hydrogen evolution reaction (HER), derived from shrimp-shell chitosan, functionalized with polyaniline (PANI), and crosslinked with glutaraldehyde (GA). The porous, hydrophilic architecture ensures rapid bubble detachment, continuous electrolyte access, and stable operation. Electrochemical analysis revealed an overpotential of 200 mV at 10 mA cm^{-2} and a charge transfer resistance of 5.1 Ω, delivering ~80% efficiency improvement over bare nickel foam. Superaerophobicity was confirmed by underwater contact angles >140° and bubble adhesion forces as low as 1.69 μN. Together, these complementary strategies establish a paradigm in intelligent coating systems, integrating thin, adherent protective films, real-time corrosion monitoring through simplified detection devices, and bio-based HER interfaces, offering sustainable and scalable pathways to unify infrastructure durability with clean energy efficiency[4].



Graphical Abstract

Keywords: CED Coating, HER, Chitosan, Acrylic Resin, Superaerophobicity.

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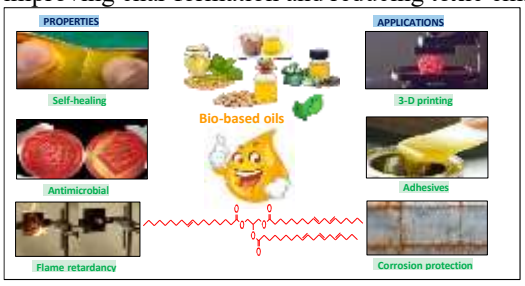
Advances in Plant-Derived Epoxy Coatings for Multifunctional Industrial Applications

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Growing interest in renewable resources as alternatives to petrochemical polymers has led to extensive research on sustainable materials. Among them, plant oil-based epoxy resins have gained prominence due to their wide availability, chemical versatility, cost-effectiveness, and eco-friendly nature. Plant oils such as soybean, linseed, castor, sunflower, palm, jatropha and Tung oil rich in unsaturated fatty acids, can be chemically modified into epoxidized derivatives. These serve as key building blocks for epoxy networks that combine sustainability with high performance, making them suitable for advanced coating applications while reducing dependence on fossil fuels. The cross-linked structures of plant oil-based epoxies act as robust barriers against oxygen, moisture, and ions.[1] These plant-based oil have application in adhesives and corrosion protection, self-healing, flame retardancy and antimicrobial activities. Their performance can be further improved with nanofillers, pigments, and tailored curing agents, enabling use in marine, automotive, and infrastructure sectors. Their polar functional groups also enhance adhesion, allowing strong bonding with metals, polymers, and composites, making them ideal for adhesives, primers, and laminating systems. Plant oil- based epoxy coatings can also be engineered for self-healing through reversible covalent bonds or embedded healing agents, enabling automatic crack repair, extending service life, and lowering maintenance costs.[2] In additive manufacturing, epoxidized vegetable oils can be converted into UV- or thermally curable resins suitable for 3D printing[3], offering renewable, strong, and design-flexible materials. Furthermore, antimicrobial properties can be integrated, making these coatings valuable for healthcare. Flame-retardant properties can be enhanced by incorporating bio-based phosphorus, nitrogen, or silicon compounds and natural nanofillers, improving char formation and reducing toxic emissions.[4]



Figures 1– Applications and properties of bio-based oils.

Keywords: Bio-based oil, Epoxy coatings, Self-healing, 3D printing, corrosion protection.

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Synthesis and Characterization of Polyester Polyols via Solvent-Free Esterification of Biobased C-36 Dimer Acid Derived from Soya Fatty Acids

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Distilled fatty acids obtained from fatty acid distillate (FAD) act as precursors for C36 dimer acids, which are synthesized through clay-catalyzed thermal polymerization. Owing to their unique structure and reactivity, dimer acids act as versatile intermediates and essential building blocks in polymer synthesis, particularly for high-performance coatings, adhesives, and elastomers.
The objective of the present study is to synthesize polyester polyols from dimer acids through solvent-free esterification, employing different types of alcohols. The aim is to develop polyester polyols with desirable physicochemical properties, enabling their use in advanced polymer applications. Dimer acid was synthesized from soya fatty acids via clay-catalyzed thermal polymerization, followed by purification through two steps of short-path distillation of the crude product. The distilled dimer acid was subsequently reacted with different types of alcohols to synthesize polyester polyols, exhibiting molecular weights in the range of 7–12 kDa, hydroxyl values of 200–400 mg KOH/g, and acid values below 5 mg KOH/g.
Polyester polyols synthesized from dimer acids represent promising precursors for the development of polyurethane coatings. Their terminal hydroxyl groups enable efficient reactivity with isocyanates, while the dimer acid backbone, derived from soya-based unsaturated fatty acids, contributes flexibility, hydrophobicity, and structural stability. As renewable and bio-based polymers, these polyols provide a sustainable alternative to conventional petroleum-derived raw materials, aligning with the growing demand for environmentally friendly coating technologies.

Keywords: Dimer Acid, Polyester Polyol, Soya fatty acid.

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Graphene-Alumina Reinforced Polymer Composites for Durable Wear and Corrosion Protection Coatings

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Industrial coatings are central to industries such as construction, mining, and, materials engineering. In industrial coatings, it is required for accelerate wear and corrosion, often resulting in premature failure, frequent replacements, and higher operational costs[1]. Addressing these challenges requires advanced protective coatings that enhance durability and performance. This study explores the development of a graphene–alumina reinforced epoxy composite as a high-performance coating[2]. Activated alumina contributes improved hardness, thermal stability, and resistance to oxidation, while graphene offers exceptional mechanical strength and self-lubricating properties. When combined, these reinforcements create a synergistic effect, significantly improving wear resistance, adhesion, and corrosion protection compared to conventional coatings. The research involves synthesizing and characterizing the hybrid composite, with key evaluations including surface adhesion, hardness, and corrosion resistance[3]. The expected outcomes are enhanced service life of industrial coatings, reduced failure rates, and improved cost efficiency in coating resistance[4,5]. By extending the operational lifespan of critical components, this innovative coating presents a sustainable and high-performance solution to meet the rising energy demands and growing exploration activities, particularly in developing economies.

Keywords: Graphene, Alumina, Composite, Wear resistance, Corrosion protection coatings.

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Self-stabilized styrene-acrylic copolymer latex with *N*-heteroatom function for improved water and corrosion resistant coatings

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The development of advanced waterborne polymer coatings with enhanced stability and performance remains a critical subject in scientific research[1–3]. In this study, a series of styrene-acrylic copolymers were synthesized with the incorporation of an *N*-heteroatom-containing functional co-monomer, *N*-vinyl pyrrolidone (NVP), in the concentration range of 17–33 mol%. A distinctive feature of this approach is the preparation of self-stabilized copolymer latexes without the use of conventional surfactants, thereby minimizing the environmental footprint and improving the long-term stability of the coatings. To benchmark the beneficial role of NVP in the emulsion polymerization process, a control latex system stabilized by a conventional surfactant was also prepared and analyzed for comparison. The self-stabilized latexes obtained through this strategy exhibited uniform particle sizes in the range of 325–371 nm and demonstrated excellent colloidal stability, as evidenced by zeta potential values exceeding +44.5 mV. Importantly, the resulting air-dried films formed from these latexes were optically transparent. The thermal, structural, microscopic, and water/alkali resistance properties of the films were evaluated and studied correlating the NVP content in the copolymer. The coating performance of the copolymer films was extensively investigated. Hydrophobicity studies indicated the NVP-modified coatings with enhanced water contact angles up to 79°. Furthermore, corrosion resistance tests on coated mild steel panels revealed significantly reduced corrosion rates, with values as low as 6.03×10^{-5} mm/year. These improvements outperformed the coatings from latex prepared via conventional emulsion polymerization. These results highlight the ability of the self-stabilized latex films to act as effective barrier coatings, protecting metallic substrates against aggressive environments. Overall, this work demonstrates the feasibility of designing self-stabilized, surfactant-free polymer latexes by harnessing the functional contribution of NVP, and deliver coatings with outstanding performances[4].

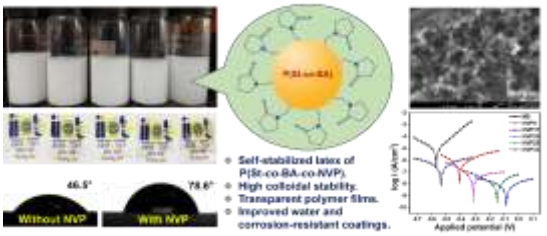


Figure 1. A graphical abstract highlighting the key stages of this study.

Keywords: Self-stabilized latex; N-vinyl pyrrolidone; Corrosion resistance; Polymer coatings; Styrene-acrylic copolymer.

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Preparation and Characterization of Fluorine containing core-shell emulsions and studying the influence of Nano-SiO_2 modifier on the properties of prepared latex for coating applications.

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Nano-SiO_2 modified fluorine-containing styrene-acrylate core-shell emulsions, consisting of styrene, butyl acrylate and 2,2,3,4,4,4-hexafluorobutyl acrylate (F6BA) was successfully synthesized by emulsion polymerization. By increasing the of nano-SiO_2 modifier content from 0 to 50 wt% significant reduction in water absorption rate of the latex films and decrease in surface tension was observed. The contact angle results showed that the prepared coatings had better water repellency and heat resistances. Furthermore, compared with fluorine-containing styrene-polyacrylate emulsion, the obtained nano-SiO_2 modified fluorine-containing emulsions proved to be highly solvent-resistant and water-resistant Comprehensive characterizations, including FTIR, XPS, DSC and TEM, confirmed the successful incorporation of F6BA into the latex copolymer and the formation of core–shell structures. By adjusting the tgs of core and the shell monomers and further modifying them with different surface modifiers it is possible to develop emulsions exhibiting higher contact angle and better water resistance providing a promising approach in the field coatings.



Figure 1: Fabrication of hydrophobic cotton fabric using nano-SiO_2 modified fluorine-containing styrene-acrylate core-shell emulsions.

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Synthesis and Characterization of Bio-Based UV-Curable Polyurethane Acrylate (PUAs) for Coating Application

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The growing demand for sustainable and environmentally friendly materials has accelerated research into bio-based polymers for advanced coating applications. In this study, a novel bio-based UV-curable polyurethane acrylate (PUA) resin was synthesized and evaluated for its potential on wood and metal substrates. The bio-based polyester polyol was reacted with isophorone diisocyanate (IPDI) and end-capped with 2-hydroxyethyl methacrylate (HEMA) to form polyurethane acrylate. Fourier-transform infrared spectroscopy (FTIR), proton nuclear magnetic resonance spectroscopy (1H-NMR), and gel permeation chromatography (GPC) were used to characterize the PUA. This synthesized polyurethane acrylate (PUA) resin was formulated with a reactive diluent and a photoinitiator and applied to both wood and metal substrates, then cured under UV radiation. The mechanical, chemical, and thermal properties of the cured films were assessed and compared with commercial polyurethane acrylate. This study highlights the viability of bio-based acid-containing PUAs as sustainable alternatives to conventional petroleum-based coatings, contributing to the development of greener materials for the coatings industry.

Keywords: Bio-based, Polyurethane acrylate, Sustainability, Coating.

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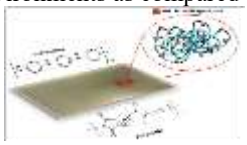
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High-Performance Corrosion Barrier: In-Situ Synthesized Fe/Mg-Doped Polyaniline– Polyimide Composite Coating

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Metal-doped polyaniline (PANI) is a promising material for anticorrosion coatings due to its ability to passivate the metal surface and potentially release corrosion inhibitors. As a conductive polymer, PANI offers excellent electrical conductivity and environmental stability. However, its application is limited by poor mechanical strength and low solubility, which compromise its structural integrity and corrosion protection performance[1,2]. Incorporating metal oxides into PANI has proven effective in enhancing its mechanical properties, thereby improving the durability and effectiveness of PANI-based coatings in harsh environments. In this study, an in-situ synthesized metal-doped polyaniline-polyimide (PANI-PI) composite coating is developed to enhance corrosion resistance. Herein, two different types of metals are doped with PANI, such as iron (F1-PANI, F3-PANI, F5-PANI) and magnesium (M1-PANI, M3-PANI, M5-PANI) with different weight percentages. The incorporation of metal dopants into the polyaniline enhances the passive film formation on metal substrates, reducing localized corrosion and increasing the charge carrier mobility within the polymer matrix, improving electron transfer kinetics in electrochemical applications[3,4]. To prepare polyimide composites, in-situ polymerization of polyamic acid (PA) and metal-doped PANI (PA, PANI/PA, F5-PANI/PA, M5-PANI/PA) have been performed. Further, it is coated on cold rolled cold annealed (CRCA) grade steel substrate and cured to prepare polyimide composite coatings. The polyimide matrix synergistically improves the coating's conductivity, adhesion, and barrier properties. Polyimide ensures thermal and mechanical stability, while polyaniline provides active corrosion inhibition through redox behavior. Electrochemical impedance spectroscopy (EIS), potentiodynamic polarization studies, and salt spray tests confirm the superior anti-corrosion performance of the synthesized coating. Electrochemical studies revealed that the F5-PANI/PI composite exhibited a higher Icorr at 82.90 nA and a corrosion rate of 37.87 e^{-3} mpy. In contrast, the M5-PANI/PI composite showed the lowest corrosion current at 32.70 nA and a corrosion rate of 14.94 e^{-3} mpy among all the coated samples, indicating superior corrosion protection performance. The metal-doped polyaniline-polyimide composite exhibits higher charge transfer resistance, reduced corrosion current density, and prolonged durability in aggressive environments as compared to normal PANI/PI.



Figures 1 – Schematic representation of metal-doped PANI/PI composite on steel substrate.

Keywords: Polyaniline; Composites; In-situ polymerization; Anti-corrosion, coatings.

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Encapsulation of Anti-algal Agent via in situ Emulsion Polymerisation

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In tropical climates, like in India, paints and coatings often face rapid aesthetic and physical damage due to spores from algae, fungi and yeast. To combat this, paint manufacturers are increasing of anti-algal agents day by day. However, factors such as rain, humidity, and weathering cause these anti-algae to leach out over time, reducing their long-term effectiveness. With the strict regulation of the anti-algal agent due to its adverse effects on ecology, there has been a constant demand to explore newer approaches to induce controlled release of these anti-algal effects. In this case, encapsulation of anti-algal agents was carried out via *in situ* emulsion polymerisation of acrylates using a bio-resourced surfactant. This encapsulated emulsion was characterised by DLS, Optical Microscopy and TEM. The leaching study of the anti-algal encapsulated emulsion and standard emulsion blending with the anti-algal agents reveals that the encapsulated emulsion exhibits a slower and continuous release of anti-algal agents compared to the standard emulsion blending with the anti-algal agents.

Keywords: Anti-algal agent, Emulsion polymerisation, Core-shell microspheres, Leaching study.

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Naphthalimide-based reversible colorimetric and luminescent sensor for detecting trace water in organic solvents

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A naphthalimide-based colorimetric and luminescent organic sensor (NMI-S2) has been developed for the rapid, visual, and quantitative detection of trace amounts of water in organic solvents such as THF, DMSO, and deuterated NMR solvents. The sensor exhibits a distinct and reversible color change upon interaction with moisture, enabling both naked-eye detection and smartphone-assisted quantification. Traditional methods for water determination, such as Karl Fischer titration and gas chromatography, although accurate, require expensive instrumentation, toxic reagents, and long analysis times.[1-2] In contrast, NMI-S2 offers a low-cost, fast, reversible, and highly sensitive alternative suitable for on-site and routine applications.

Structurally, NMI-S2 features amine and amide functionalities that participate in hydrogen bonding, a tri-alkoxy benzene wedge promoting hydrophobic interactions, and a naphthalimide π-chromophore facilitating π–π stacking. These features endow the probe with strong self-assembly capability and supramolecular responsiveness. In dry THF, NMI-S2 exists mainly in a monomeric state, exhibiting absorption bands between 300–350 nm (π–π* transition) and 365–480 nm (intramolecular charge transfer, ICT). Upon incremental addition of fluoride ions (0–8 equivalents), systematic hypochromic and bathochromic shifts occur, along with the emergence of a new shoulder band near 500 nm. These changes indicate supramolecular polymerization of NMI-S2 driven by synergistic hydrogen bonding, π–π stacking, and hydrophobic interactions.[3]

At higher fluoride concentrations, the UV–Vis spectrum reveals a pronounced bathochromic shift and an observable color change from greenish yellow to brown. This is attributed to deprotonation of the C4 amine, which enhances the ICT push–pull character and increases electronic delocalization, giving rise to an anionic, polymeric form (NMI-S2·F). Importantly, this process is reversible—upon exposure to trace water, reprotonation occurs, restoring the monomeric state and original optical properties.

This reversible fluoride–water-mediated supramolecular polymerization–depolymerization mechanism underpins the sensor's high sensitivity and reproducibility. Furthermore, color chart visualization and smartphone-based colorimetric analysis enable facile, real-time quantification of water in organic solvents and solid samples (e.g., salts, sugars).[4] Thus, NMI-S2 represents a practical and efficient supramolecular sensing platform for trace moisture detection, offering a promising alternative to conventional analytical techniques for use in chemical, pharmaceutical, and environmental monitoring applications.

Keywords: Supramolecular polymerization; Naphthalimide sensor; Colorimetric detection; Moisture sensing.

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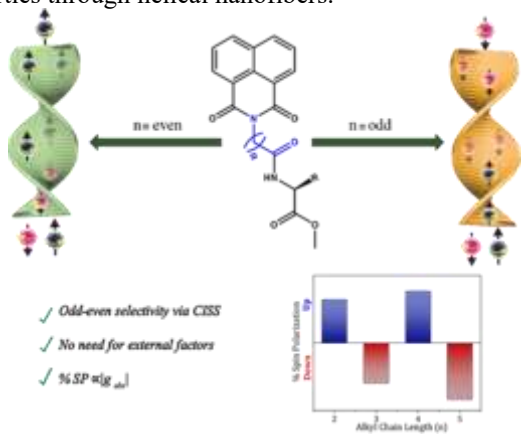
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Chirality Induced Odd-Even Spin Selectivity in Self-Assembled Peptide-Based Helical Nanofibers

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Chiral organic molecules are emerging as key materials in the field of spintronics, primarily due to the chirality-induced spin selectivity (CISS) effect. This phenomenon has provided valuable insights into how non-magnetic chiral structures can exhibit significant spin selectivity exclusively as a result of their inherent chirality. Previous studies on CISS in organic molecules have primarily focused on cases where spin polarization arises from the intrinsic chirality of monomers or from achiral monomers influenced by a chiral solvent. However, there has been no experimental evidence demonstrating that an achiral segment within a molecule, even in the presence of a chiral group, can drive the CISS effect. Here, we report the first experimental observation of the CISS effect in peptide-based helical nanofibers, where spin selectivity can be switched by altering the length of achiral spacers between the rigid chromophore and the chiral terminal residue. Our findings reveal a distinct odd-even effect: molecules with an even number of methylene spacers exhibit one type of spin selectivity, while those with an odd number of methylene spacers display the opposite spin preference. We have utilized magnetic field-dependent atomic force microscopy (mc-AFM) and Kelvin probe force microscopy (KPFM) techniques to demonstrate a robust relationship between chirality and spin transfer. Furthermore, for the first time, we have successfully demonstrated a novel approach by investigating the role of solvent ratio on the spin-dependent transport properties through helical nanofibers.



Keywords: Chirality-induced spin selectivity (CISS) effect, Spintronics, Peptide-based self-assembly, Supramolecular polymers, Spin filters.

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Spin Filtering and Amplification in Self-assembled Nanofibers Based on Chiral Asymmetric Building Blocks

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The cooperativity in artificial self-assembling systems can be enhanced to expand their applications and redesign their properties. Recently, chiral molecules have garnered renewed attention due to their potential as highly efficient spin filters through the chiral-induced spin selectivity (CISS) effect. However, the potential of asymmetric building blocks based on chiral perylene diimides (PDIs) self-assembled materials to generate spin-polarized current is still not widely acknowledged. In this work, we have demonstrated that nanofibers derived from "asymmetric PDIs" molecules have been found to exhibit promising spin-filtering property and the amplification of spin polarization at room temperature. Also, the exploration of chiral amplification and correlating it with the amplification of spin polarization has been reported for the first time through this work. These findings underscore the significance of self-assembled materials in the realm of spintronics, as they offer fascinating platforms with evolving structure-property relationship. It also provides the feasible possibility of enhancing the CISS-based spintronic devices that can accomplish controllability, and high spin-filtering efficiency simultaneously.

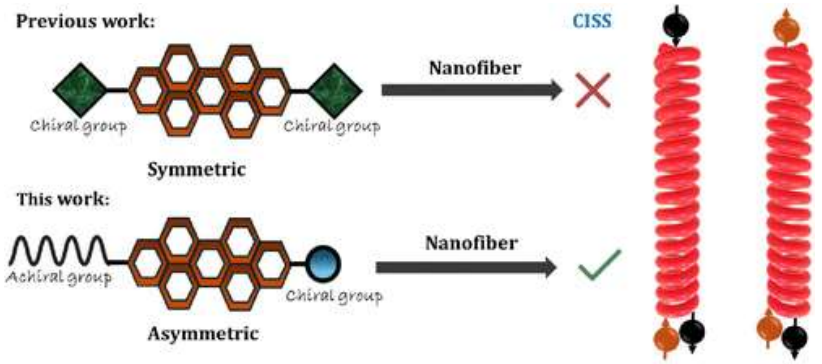


Figure: Schematic representation of the current study including nanofiber materials based on asymmetric PDI molecules for observing the CISS effect.

Keywords: Chirality Induced Spin Selectivity, Supramolecules, Chiral Polymers, Spintronics, Quantum Mechanics.

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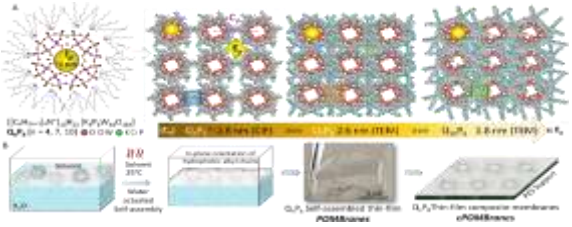
Counterion-directed supramolecular assembly of polyoxometalates into fixed-pore crystalline thin film for molecular separation

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Precise control of pore size at the angstrom scale is critical for advancing membrane technologies capable of high-resolution separations[1]. Biological membranes, such as aquaporins[2], achieve exceptional selectivity through well-defined nanopores. In contrast, conventional polymer membranes possess disordered, dynamic pore networks due to inefficient chain packing, leading to a fundamental permeability–selectivity trade-off. While crystalline porous materials like MOFs, COFs, and zeolites offer fixed and uniform pores, their practical application is hindered by limited mechanical strength, processability challenges, and difficulty in fabricating large-area, defect-free films while preserving their structural order. Here, we introduce POMbranes, a class of crystalline thin-film membranes assembled from crown-type polyoxometalate (POM) clusters[3], $[P_8W_{48}O_{184}]^{40-}$ (P_8). These P_8 clusters contain intrinsic ~1 nm pore defined with crystallographic precision, ideal for molecular sieving4. By functionalizing P_8 with alkylammonium counterions ($[C_nH_{+1}]_4N^+$,n = 4, 7, 10)5, we direct supramolecular self-assembly into continuous, defect-free thin films with ordered, permanent porosity. Tuning the alkyl chain length adjusts the extrinsic porosity (E_p) between clusters without disrupting the intrinsic pore network (I_p). Shorter chains (Q_4P_8) enable dual-path transport via I_p and E_p, whereas longer chains (Q_7P_8, $Q_{10}P_8$) restrict transport solely through I_p, enabling precise molecular sieving. These ultrathin selective layers (~30– 500 nm) can be fabricated over large areas (~50 cm²). POMbranes demonstrate single-digit pore selectivity and tenfold higher separation efficiency for molecules differing by only 100–200 Da compared to state-of-the-art membranes, offering a scalable strategy to translate molecular design into practical, high-performance separation technologies.

Figure 1: Constituents of Q_4P_8, Q_7P_8, $Q_{10}P_8$ *POMbranes*.



keywords: POMbranes, supramolecular assembly, intrinsic pores, molecular separation.

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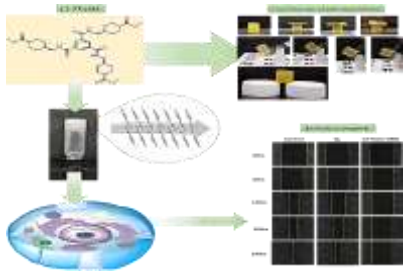
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Designing tranexamic acid based Supramolecular Gel and evaluation of their self-drug delivery application

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Tranexamic acid (TXA) is a non-essential amino acid widely used as an antifibrinolytic to reduce surgical and trauma-related bleeding by blocking plasminogen binding to fibrin. Supramolecular gels offer a complementary strategy where low molecular weight gelators (LMWGs) self-assemble through noncovalent interactions into one dimensional nanofibers that entangle to form a self-assembled fibrillar network (SAFIN),immobilizing solvent and enabling minimally invasive, localized delivery. Designing novel TXA based supramolecular gelators are especially attractive as they could combine intrinsic hemostatic action with the structural and delivery advantages of gels. Here, we report the design, synthesis, and biological evaluation of a series of TXA-conjugated LMWGs that form robust supramolecular gels and demonstrated instant gelation without any external stimuli. Gelation was screened across aqueous and mixed biogenic solvents and confirmed by the inverted vial method. Morphological characterization (TEM/SEM) revealed a dense fibrillar network responsible for mechanical integrity, while rheological measurements demonstrated low tan δ values which confirms robustness of the gel. Single-crystal X-ray diffraction (SXRD) of newly designed gelators established a strong structure−property (gelation) correlation and hydrogen bond directed one-dimensional assembly. Across six gelators, the C3-TXAME in methyl salicylate showed multifunctional characteristics including self-healing, load-bearing, and adhesive properties. A xerogel of C3-TXAME in DMSO–water further showed potentiality as a drug-delivery carrier. Biological activity of this xerogel was assessed in melanoma (B16-F10) and non-malignant cell lines (HEK 293; E. Derm(NBL-6)). C3-TXAME showed dose-dependent activity against B16-F10 cells while remaining largely non-cytotoxic toward normal cells at relevant concentrations, indicating a promising therapeutic window. Mechanistic studies, including migration assay, cell- cycle analysis mitochondrial membrane potential analysis and apoptosis via Annexin-V–FITC/PI assays, supported an anticancer effect consistent with apoptosis induction. Together with rheological evidence (storage-modulus dominance) of gel-like behavior, these data establish that TXA-derived gelators can simultaneously provide structural integrity for localized application, and this platform may diminish the systemic liabilities of TXA in humans by enabling localized, sustained exposure, and it opens a path toward minimally invasive treatments for local hemostatic and therapeutic/combination-therapy vehicle for surgery, trauma care, and oncology, where concentrating activity at the target site could enhance efficacy.



Scheme: Overall representation of work.

Keywords: Supramolecular gel, Single crystal X-ray diffraction, Wound healing, Biomaterials.

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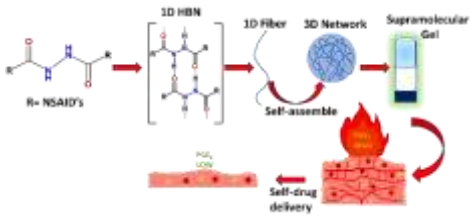
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Nonsteroidal Anti-Inflammatory Drug (NSAID)-Conjugated Bisamide System Exhibiting Remarkable Gelation Ability, Biocompatibility, and Anti-Inflammatory Activity for Drug Delivery Applications

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Nonsteroidal anti-inflammatory drugs (NSAIDs) are first-line agents for pain and inflammation that act primarily by inhibiting cyclooxygenase (COX)–mediated prostaglandin biosynthesis. While effective, their chronic systemic use is limited by gastrointestinal, renal, and cardiovascular adverse effects, motivating strategies that localize delivery and reduce peak systemic exposure. Supramolecular gels designed from small molecules offer a promising route for site-specific, minimally invasive therapies as their core small-molecule self-assemble into a 3D network via weak, interactions like hydrogen bonds and hydrophobic forces, allowing them to form in situ. Their high-water content and tunable properties make them biocompatible and their non-covalent crosslinks enables the controlled, sustained release of self or co-delivered therapeutic agents with high efficacy. These small molecules based supramolecular gels can also be designed in such a way where pharmacophore (small molecule) itself act as gelator and deliver the drug without any external carrier. The process is known as vehicle free drug delivery (VFDD) system. Here We report the design, synthesis, and biological evaluation of NSAID's–conjugated bisamide small-molecules that self-assembles into stable gels and simultaneously retain anti-inflammatory function. The bisamide scaffold was functionalized at both termini with an NSAID. The gelation ability was assessed in a range of aqueous and mixed biogenic solvent systems. Among the tested compounds, the naproxen-conjugated bisamide (NAP_BISA) was identified as a supergelator, exhibiting a minimum gelation concentration (MGC) below 1 wt% and demonstrating instant gelation in the absence of any external stimuli. Morphological characterization (TEM/SEM) revealed a dense fibrillar network responsible for mechanical integrity, while rheological measurements demonstrated storage modulus (G′) values which confirms robustness of the gel. Single-crystal X-ray diffraction (SXRD) of newly designed gelators established a strong structure−property (gelation) correlation and hydrogen bond directed assembly. Biocompatibility and bioactivity were assessed using RAW 264.7 macrophages. The gelators exhibited >85% cell viability at therapeutically relevant concentrations, indicating acceptable cytocompatibility. In lipopolysaccharide (LPS)–stimulated macrophages, NAP_BISA significantly reduced prostaglandin E2 (PGE2) production, demonstrating that the conjugated NSAID remains functionally accessible even within the gel matrix. Beyond intrinsic anti-inflammatory activity, the NAP_BISA aqueous gel served as a versatile carrier for co-therapeutic delivery as it efficiently loaded the anticancer drug doxorubicin and the anti-inflammatory agent sulfasalazine and released both in a *p*H responsive manner. Collectively, these data identify NSAID-conjugated bisamide as dual function materials, structural gelators and active therapeutics that can trigger NSAID action at the target site while simultaneously providing controlled release of co-loaded drugs.



Keywords: Bisamides. Gels. Supramolecular chemistry. X-ray diffraction. Anti-inflammation.

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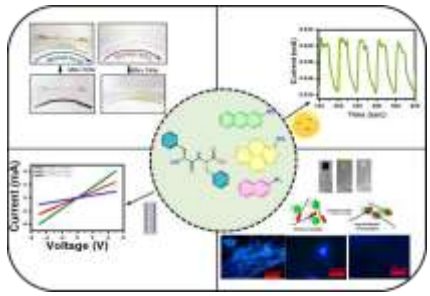
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Donor–Acceptor Peptide Supramolecular Gels with Nanomaterials Doping for enhanced Optoelectronic and Energy-Storage Performance

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Supramolecular gels with tailored optoelectronic behavior are of increasing interest for applications in soft electronics, sensing, and energy-related devices [1,2]. Herein, we investigate the donor–acceptor interactions of three aromatic amine donors, 2-aminoanthracene, 1-aminopyrene, and 2- aminonaphthalene, with diphenylalanine as the acceptor, in both solution and gel phases. In solution, molar ratio studies revealed that the 2-aminoanthracene–diphenylalanine system displayed the strongest charge-transfer interaction, evident from a pronounced color change within 24 hours. The pyrene and naphthalene systems showed weaker charge-transfer responses under identical conditions. Increasing the concentration of the donor and acceptor yielded stable supramolecular gels [3], where similar charge- transfer trends were observed. Anthracene–diphenylalanine gels exhibited the fastest and most prominent optical and spectroscopic changes, followed by pyrene and naphthalene. The mechanical strength of the gels was evaluated by rheology, and structural characterization by PXRD, FTIR, TEM, and fluorescence microscopy confirmed the presence of crystalline fibrous networks across all systems. Conductivity and photocurrent measurements further demonstrated that anthracene–diphenylalanine gels possessed superior electronic performance compared to the other donor–acceptor assemblies. To further enhance the functional properties, nanomaterials [4] such as graphene oxide (GO), graphene quantum dots (GQD), and carbon nanotubes (CNT) were incorporated into the gels. Notably, CNT- doped gels exhibited the most significant improvements, showing enhanced conductivity and electron storage capacity. This enhancement is attributed to improved charge delocalization and the creation of efficient transport pathways within the fibrous matrix.
In summary, this work establishes di phenylalanine-based donor–acceptor gels, particularly those incorporating 2-aminoanthracene, as versatile materials with promising optoelectronic features. The incorporation of CNT provides a simple yet effective strategy to boost conductivity and energy-storage performance, opening new opportunities for developing soft, hybrid materials for advanced electronic and energy applications. The novelty of this work lies in correlating molecular-level CT interactions with gel-phase properties, systematically evaluating nanomaterial doping strategies, and positioning peptide supramolecular gels as functional optoelectronic platforms beyond their traditional biomedical roles.



Keywords: Organogels, Charge-transfer interaction, Optoelectronic materials, Carbon nanomaterials, Photocurrent.

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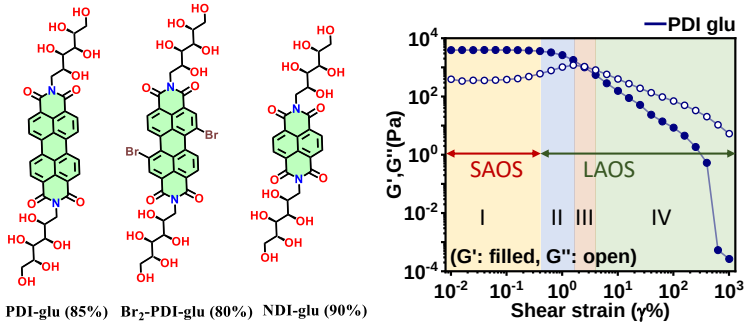
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Self-Assembly and Mechanical Properties of a Chiral, π-Chromophoric D-Glucamine Hydrogel

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This study investigated the influence of molecular structure on the optical and mechanical properties of self-assembled hydrogels. Three amphiphilic derivatives were synthesized by functionalizing chiral D-glucamine (Glu) with different pi-chromophoric core to have PDI-glu, Br_2-PDI-glu, NDI-glu in such a way that every moiety contained a large hydrophobic pi-surface and a hydrophilic D-glucamine which drove their self-assembly in water. Assemblies which were successfully prepared from each derivative in a borate buffer solution (1M, pH= 8.5), formed robust fibrillar network of hydrogel by interacting of π-π surface stacking core and dynamic cross-linking between intermolecular syn-diol units of glucamine and borate ions. Photophysical properties of the assemblies were characterized using absorption, emission, circular dichroism (CD), time-correlated single photon counting (TCSPC) spectroscopy. Overall morphology was also checked by FESEM. Viscoelastic responses of hydrogel networks were extensively investigated in both linear and nonlinear regimes. To gain deeper insight into their microstructural response, 3D Lissajous-Bowditch curves were analyzed and key nonlinear moduli (G'_M, G'_L, η'_M, and η'_L) were estimated. From these moduli, the strain-stiffening (S) and shear-thinning (T) parameters were derived for each hydrogel, providing a qualitative link between the chromophore structure and the viscoelastic behavior of self-assembled system.



Keywords: Hydrogel, self-assembly, chromophore, photo-physical, LAOS.

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Crowding induced Secondary Nucleation in Supramolecular Polymerization

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The intracellular environment is highly crowded with macromolecules, generating excluded volume effects that govern hierarchical self-assembly in biological systems. Such crowding, exemplified by chaperone-assisted protein folding and stabilization of polypeptides, accelerates nucleation and drives higher-order morphologies.[1] While extensively explored in natural biomolecular assemblies, the influence of macromolecular crowding on synthetic supramolecular architectures remains underexplored. Here, we investigate excluded volume effects using noninteracting macromolecular crowders and reveal their role in modulating supramolecular polymerization. Crowding accelerates nucleation and elongation by enhancing local monomer concentration, stabilizes otherwise inaccessible morphologies, and induces secondary nucleation pathways that guide fiber transformations. Kinetic analyses further demonstrate how crowding, in conjunction with medium viscosity, governs elongation dynamics and hierarchical morphology. These insights establish macromolecular crowding as a key regulator of supramolecular polymer growth and provide a biomimetic framework for rationally directing nucleation, kinetics, and higher-order material design.

Keywords: Macromolecular Crowding, Supramolecular Polymerization, Secondary Nucleation.

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Photo Induced Aggregation of Bay-substituted Cationic Perylene Diimide Derivatives and its Bioimaging Application

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Two water-soluble cationic perylene diimide (PDI) derivatives, named PDI-2N and PDI-1N, have been designed and successfully developed to investigate their unique photochromic behavior in a polar protic medium. Spectroscopic and structural analyses have confirmed that a photocyclization reaction occurs upon light illumination, converting the PDI backbones concurrently to annulated coronene diimide (CDI) moieties. Aggregation studies before and after photocyclization, supported by energetic and structural analysis from molecular dynamic simulations, have provided insights at the molecular level. Both chromophores exhibit high singlet oxygen ($^1O_2$) generation efficiencies of 0.6 and 0.72, as measured using a DPBF probe with rose bengal as a reference. Cell uptake studies have confirmed their non-toxic nature and efficient lysosomal localization. Intracellular ROS generation observed under visible light irradiation results in cytotoxicity. These results highlight the potential of these PDI derivatives as promising photosensitizers for photodynamic therapy applications in a biological environment.

Key words: Perylene diimide (PDI), Coronene diimide (CDI), Photocyclization, and photodynamic therapy (PDT).

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Supramolecularly Cross-linked Nanoassemblies for High Encapsulation Stability and Controlled Guest Release

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The design of amphiphilic macromolecules is of great interest due to their applications in various fields of materials and biomedical science, for example, drug delivery,[1] gene transfection,[2] cell imaging,[3] etc. Specifically, in the context of drug delivery applications, stimuli responsive amphiphilic polymers are widely used as they are capable of self-assembling into various supramolecular nanostructures. The stimuli responsive functionality has been installed to the polymeric structure for location specific triggered guest release and thus overcoming the poor selectivity and severe side effects of chemotherapeutic treatments. Therefore, the design and development of structurally robust nanocarriers with enhanced noncovalent encapsulation stability is highly desirable to improve their performance and reliability.

In this study, a new self-immolative amphiphilic polyurethane[4] was synthesized, incorporating redox-responsive disulfide bond, tertiary amines and aromatic units integrated into a polymer backbone, along with regularly spaced tetra ethylene glycol monomethyl ether pendants. In aqueous media the polymer spontaneously forms micelle like nano-assemblies that effectively encapsulate hydrophobic guest molecules. Beyond hydrophobic interactions, the structural integrity of the micellar core is enhanced by supramolecular cross-linking through π-π stacking between aromatic moieties and hydrogen bonding *via* urethane groups. These combined interactions significantly enhance guest encapsulation stability.

In contrast, a second polyurethane was synthesized, incorporating disulfide linkages, tertiary amine groups and aliphatic segments within the polymer backbone, along with periodically distributed tetra ethylene glycol monomethyl ether pendants. In aqueous medium, this polymer also forms micelle like nano-assemblies capable of encapsulating hydrophobic guest molecules through supramolecular cross-linking. However, the encapsulation efficiency of this system is comparatively lower than that of the previously described polyurethane. This reduced performance is attributed to the absence of aromatic moieties, resulting in stabilization primarily through H bonding *via* urethane groups in addition to hydrophobic interactions. The detail self-assembly, characterization, guest encapsulations and triggered release will be the topic of the poster presentation.

Keywords: amphiphilic polyurethane, self-immolative linker, nanoassembly, supramolecular crosslinking, redox-responsiveness.

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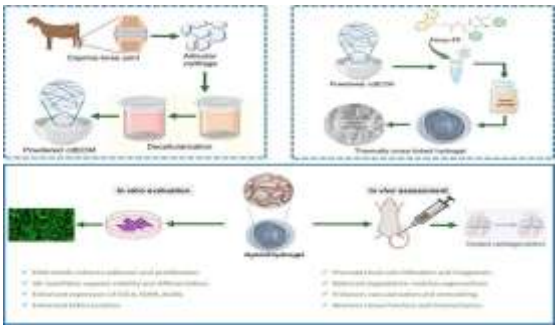
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Supramolecularly reinforced dECM hydrogels enabling resilient scaffolds for cartilage regeneration

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Articular cartilage regeneration is inherently challenging due to its complex zonal architecture, absence of vascularization, and restricted intrinsic repair capacity. Conventional treatments such as microfracture and mosaicplasty often fail to provide durable restoration, underscoring the demand for biomaterial-based strategies that integrate mechanical robustness with native-like biochemical cues[1]. While both natural and synthetic polymers have been explored, most scaffolds struggle to balance two essential features: mechanical robustness for load-bearing and biochemical fidelity for phenotype maintenance[2]. To address this, a hybrid supramolecular hydrogel was engineered by combining decellularized extracellular matrix (dECM) with self-assembling fluorenylmethoxycarbonyl-diphenylalanine (Fmoc-FF) peptide nanofibers[3,4]. The interpenetration of peptide nanostructures within the dECM scaffold, mediated by hydrogen bonding and aromatic π–π interactions, established a hierarchically organized network with markedly enhanced physicochemical and biological properties. Rheological characterization revealed a substantial increase in storage modulus (G′) from 8.1516 Pa in dECM alone to 16642 Pa in the hybrid system, representing a ~2000-fold enhancement[5]. The hydrogel maintained physiologically relevant swelling and porosity, and scanning electron microscopy confirmed a nanofibrous architecture. FTIR spectra exhibited β-sheet signatures at 1645 cm^{-1} and 1695 cm^{-1}, validating peptide self-assembly within the matrix. Biologically, the construct supported high cell viability (>85%) and also exhibited sustained proliferation, and maintained their chondrogenic phenotype over extended culture periods, underscoring the synergy between supramolecular reinforcement and matrix-derived bioactivity. Collectively, these findings demonstrate that supramolecular reinforcement of dECM via peptide nanofibers transforms a mechanically fragile matrix into a load-bearing, bioactive scaffold, highlighting its strong potential for advancing cartilage tissue engineering.



Scheme 1 – Schematic illustration of the fabrication of peptide–ECM hybrid hydrogels and their subsequent in vitro and in vivo evaluation. The hybrid system enhances cellular responses and facilitates cartilage repair with restoration of structural and functional properties.

Keywords: Supramolecular Assembly, Short Peptide, Hydrogel, Cartilage Regeneration, Mechanical Reinforcement.

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Stereocomplex Crystallization Induced Energy Transfer in Enantiomeric Blends of Chromophore-Appended Poly(lactide)s

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The development of polymer-based donor-acceptor (D-A) systems with tunable photophysical properties holds significant potential for applications in organic electronics, photovoltaics, and fluorescence-based sensing. Here, we report a novel D-A polymer system comprising dihydroxy-functionalized oligo(p-phenylene vinylene) (OPV) as the donor and dihydroxy-functionalized perylene diimide (PDI) as the acceptor. These chromophores were covalently incorporated into the backbones of poly(L-lactic acid) (PLLA) and poly(D-lactic acid) (PDLA), respectively, yielding stereoregular, biodegradable OPV–PLLA and PDI–PDLA polymers with nearly identical molecular weights. The enantiomerically pure PLLA and PDLA chains facilitate the formation of stereocomplexes (SCs) in both gel and solid states, thereby enabling Förster resonance energy transfer (FRET) from OPV to PDI. The photophysical properties of OPV–PLLA, PDI–PDLA, and their 1:1 blend were systematically investigated in solution, gel, and solid states. In solution, both polymers displayed monomeric emission features. In contrast, the 1:1 blend exhibited broadened emission profiles in the gel and solid states. Notably, in the gel state, the blend showed pronounced donor fluorescence quenching accompanied by enhanced acceptor emission, confirming efficient FRET. In the solid state, however, fluorescence quenching dominated due to the aggregation-caused quenching (ACQ) effect of PDI. This work demonstrates that covalent integration of π-conjugated chromophores into biodegradable polymer matrices provides an effective strategy for designing environmentally friendly optoelectronic materials with tunable donor-acceptor interactions.

Keywords: Poly(L-lactic acid), Poly(D-lactic acid), Stereocomplex, FRET, Aggregation-caused quenching.

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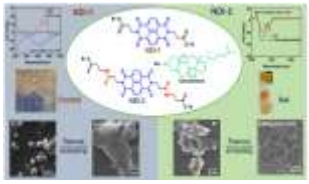
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Structure-Property Relationships in Cholesterol–Naphthalene Diimide Conjugates via Pathway-Complexity in Supramolecular Self-Assembly

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Pathway complexity in supramolecular self-assembly provides a powerful strategy to regulate nanostructures and thereby tune their functional properties. In contrast to conventional single-pathway assembly, pathway complexity allows multiple competing routes that can lead to distinct structures and functions depending on external conditions such as solvent composition, temperature, or rate of assembly. This dynamic behavior not only deepens our understanding of supramolecular chemistry but also offers opportunities for designing responsive and tunable materials. Small structural variations can strongly influence the assembly process, giving rise to distinct morphology, optical behaviors, and material characteristics. In this study, we explored how a small structural modification governs the self-assembly of cholesterol-appended naphthalene diimide (NDI) derivatives and uncovered distinct pathway-dependent properties. Two conjugates were synthesized: NDI-1, lacking an amide linker and NDI-2 incorporating an amide linker (Scheme 1). Although both derivatives displayed pathway complexity, they followed strikingly different assembly routes. Spectroscopic studies showed that both molecules remained monomeric in tetrachloroethane (TCE), but aggregation was induced upon the addition of acetonitrile (ACN). X-ray diffraction (XRD) further revealed crystalline packing in NDI-1 and amorphous organization in NDI-2, underscoring the strong influence of hydrogen bonding introduced by the amide linker. Morphological investigations provided additional insights into their temperature-dependent self-assembly. NDI-1 initially formed small particles at room temperature, preserved these under rapid cooling from high temperature, but reorganized into larger 2D sheets upon slow cooling. This behavior highlights the coexistence of kinetic and thermodynamic states and the influence of temperature on pathway complexity. In contrast, NDI-2 first produced 2D sheets as the kinetic product, which then transformed into thermodynamically stable left-handed twisted fibers upon thermal annealing, further demonstrating the role of pathway complexity in dictating morphology. The chiroptical responses of the two derivatives also differed significantly. NDI-1 exhibited an inversion of circular dichroism (CD) signals from P-type to M-type upon cooling, demonstrating temperature-controlled chiroptical switching. In addition, NDI-1 displayed aggregation-induced cyan emission, further highlighting its functional tunability. NDI-2, however, stabilized directly in an M-type helical arrangement without subsequent inversion. Importantly, gelation studies revealed that only NDI-2 formed a stable gel in TCE/ACN mixtures, while NDI-1 formed small crystals in solution, establishing the decisive role of amide hydrogen bonding in stabilizing higher-order supramolecular architectures. Overall, this work demonstrates that even one amide bond can strongly change the assembly pathway, packing, and properties of the system. Such small structural changes allow control over nanostructures, optical activity, and emission, opening the way to applications in optoelectronics, sensing, bioimaging, and smart soft materials.

Scheme 1: Temperature-dependent pathway complexity in self-assembly of NDI-1 and NDI-2 and their comparative self-assembly studies.



Keywords: Supramolecular self-assembly, Pathway complexity, Nanostructures, Chiroptical properties.

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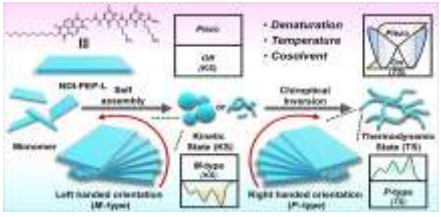
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Pathway Complexity Driven Chiroptical Switching and Tunable Piezoelectric Behavior in Peptide Self-Assembly

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Sustainable and adaptable piezoelectric materials are increasingly essential for next-generation technologies in green energy, soft electronics, and environmental monitoring. Their potential in advanced sensing, actuation, and energy-harvesting applications is widely recognized, yet precise and dynamic control over piezoelectric responses in molecular systems remains a major challenge. Here, we present a supramolecular strategy to achieve piezoelectric behavior using naphthalene diimide (NDI)-conjugated tetrapeptides, NDI-PEP-L and its enantiomer NDI-PEP-D, where pathway complexity governs tunable self-assembly, supramolecular chirality, and functional properties (Figure. 1). In aqueous media, NDI-PEP-L initially forms kinetically trapped aggregates (KS-I) consisting of short nanorods with M-type (left-handed) helical arrangement of chromophores, stabilized by π-π stacking, hydrogen bonding, and hydrophobic interactions of the NDI chromophore and peptide backbone. Introducing a cosolvent (20% DMSO/H_2O) yields a second kinetically trapped state (KS-II) of irregular nanoparticles, retaining M-type chirality. Variable-temperature UV-vis and CD spectroscopy reveal that cooperative supramolecular polymerization occurs upon thermal annealing or slow cooling, transforming KS-II into a thermodynamically stable state (TS) comprised of long, crosslinked nanofibers exhibiting P-type (right-handed) helical organization, demonstrating the chiroptical switching. Denaturation studies further demonstrate direct chiroptical inversion from KS-I to TS through a non-chiral intermediate even at high cosolvent concentrations (~80% DMSO). Piezoelectric characterization using piezoresponse force microscopy (PFM) demonstrates that KS-I and KS-II display negligible piezoresponse due to multidirectional, short-range dipolar arrangements. In contrast, TS exhibits piezoresponse, indicating highly ordered, unidirectional dipole alignment within the fibrillar network indicating highly ordered, unidirectional dipole alignment within the fibrillar network. This direct correlation between supramolecular organization and piezoelectric functionality establishes the critical role of pathway-controlled self-assembly in dictating electromechanical properties. Overall, these findings highlight a versatile, bioinspired strategy to dynamically control chiroptical and piezoelectric behavior in peptide-based nanomaterials. By modulating solvent composition, temperature, and denaturation conditions, it is possible to change between kinetically trapped and thermodynamically stable assemblies, enabling precise control over nanostructure morphology, supramolecular chirality, and functional output. By linking molecular design, self-assembly pathways, and emergent functionality, this study establishes a general framework for rationally designing peptide-based nanostructures with programmable piezoelectric responses. The approach underscores the broader potential of peptide-based materials in constructing high-performance, tunable, and sustainable functional systems, offering new opportunities for next-generation bioinspired smart devices and adaptive soft materials.



Keywords: Self-assembly, Peptides, Chiroptical switching, Piezoelectric response

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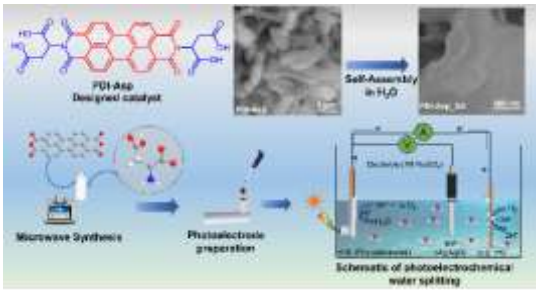
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Harnessing Supramolecular Self-Assembly for Enhanced Electrocatalytic Hydrogen Evolution via Water-Splitting

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As the world's energy demands continue to rise, producing green hydrogen through photoelectrochemical (PEC) methods stands out as a highly promising solution for a cleaner and more sustainable future. While numerous reports highlight the use of inorganic materials as catalysts for water splitting to generate hydrogen (H_2), only a limited number of organic molecular systems have been explored for achieving hydrogen production through this approach. The development of the organic based catalyst for this application is regarded as most promising avenues to solve the environmental issue. Recently, perylene diimide (PDI)-based supramolecular photoelectrocatalysts have attracted considerable attention due to their broad applicability, particularly in water splitting for sustainable H_2 generation.[1,2] Herein, we have designed and synthesized an aspartic acid-functionalized perylene diimide derivative (PDI-Asp) as organic photoelectrocatalyst for PEC water splitting (Fig. 1). The introduction of amino acid functionality enhances aqueous solubility, enables hydrogen bonding, and promotes directional supramolecular self-assembly through π–π stacking and other non-covalent interactions. Photophysical studies, including UV-Vis-NIR and photoluminescence spectroscopy, revealed its potential as an efficient photoelectrocatalyst. Electrochemical analysis revealed that the bulk disordered form of PDI-Asp exhibits significant photocurrent, validating its intrinsic catalytic potential. To further explore the role of molecular organization, we investigated its self-assembled state in water. Interestingly, the self-assembled PDI-Asp demonstrated a 1.8-fold enhancement in photocurrent compared to the bulk form. Morphological characterization indicates a transition from short nanotape-like aggregates to extended two-dimensional nanosheet architectures during self-assembly. These nanosheets provide a significantly larger interfacial surface area and an interconnected hydrogen-bonded framework that facilitates efficient exciton dissociation, electron-hole separation, and charge transport. In the bulk state, charge recombination and limited transport pathways suppress catalytic efficiency. In contrast, the ordered nanosheet assemblies minimize recombination losses, enhance charge delocalization across π-stacked domains, and enable superior PEC water-splitting performance through the electron transport through the π-surface. In summary, we demonstrate that PDI-Asp functions as an efficient, organic photocatalyst whose performance is markedly improved for self-assembled system. Our results offer a rational design strategy for developing next-generation organic photocatalysts based on controlled molecular self-assembly, with broader implications for energy conversion and sustainable H_2 generation.



Keywords: Supramolecular Self-assembly, Water splitting, Photoelectrocatalysis, Hydrogen evolution.

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Peptide-Induced Chirality Transfer and Circularly Polarized Luminescence in Achiral BODIPY Emitters via Halogen Bonding

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Abstract: The presented work concerns the design of chirality transfer through halogen bonding to induce circularly polarized luminescence (CPL)[1,2] in achiral molecules. By introducing a newly designed peptide[3], D_1 functionalized with an iodine-substituted perfluorobenzene[4], two achiral BODIPY dyes, A_1 and A_2 achieved halogen bonding with the former and co-assembled to give D_1-A_1 and D_1-A_2 complexes. These co-assemblies showed unique optical characteristics: a large bathochromic shift and an intensity increase of emission by a factor of two compared to that of D_1-A_2, indicating the difference in molecular packing of BODIPY dyes. Chirality transfer was confirmed by using CD and CPL measurements. Both co-assemblies showed new CD and CPL signals, and measured g_{lum} values were -1.2×10^{-2} for D_1-A_1 and -0.91×10^{-2} for D_1-A_2. Meanwhile, thermal stability tests showed that, below 75°C, the co-assemblies retain supramolecular chirality, while D_1-A_2 showed higher stability due to strong hydrophobic interactions. Transmission electron microscopy has shown different morphologies for D_1-A_1 (nanorods) and D_1-A_2 (fibrillar structures), which further confirms the different self-assembly behaviours. Spectroscopic analyses confirmed that the chirality transfer takes place by halogen bonding, evidenced by shifts of B-F stretching frequencies, further confirmed by ^{19}F and ^{11}B NMR studies. The current work points out the efficiency of halogen bonding as an efficient modular approach to induce chirality and CPL in achiral molecules and opens new avenues to the design of stimulus-responsive optoelectronic materials. The experimental results give grounds for the development of noncovalent interactions in chiral material development and in systems of molecular recognition.



Keywords: CPL, Halogen Bonding, Chiral Induction, Peptide Assembly.

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Tryptophan-Derived Minimalistic Supramolecular Hydrogel as a Tunable Catalytic Platform for Enzyme Mimetic Activity and Water Remediation

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Single amino acids and their derivatives exhibit an exceptional ability to self-assemble into ordered nanostructures that render potential catalytic activity[1,2]. Although there are numerous instances of catalysis using peptide nanostructures inspired by amyloid fibres[3,4], hydrogel-based catalysts produced from a single amino acid are few. In this work, we report the self-assembly of N-fluorenylmethyloxycarbonyl-L-tryptophan (FT) into a nanofibrous hydrogel capable of catalyzing the hydrolysis of p-nitrophenyl acetate via indole-assisted microenvironmental effects. The FT hydrogel displays pathway complexity, transitioning from kinetically trapped nanofibers to thermodynamically stable semicrystalline aggregates with enhanced catalytic activity, as evidenced by comparative studies with the monomers and the gel fibers.[3] Functional performance was further improved by nanoengineering the FT network with graphene oxide and graphene quantum dots, yielding composites with enhanced mechanical strength and enzyme-like hydrolase activity, supported by Michaelis-Menten kinetic analysis. Additionally, in situ reduction of Au^{3+} within the FT matrix produced AuNPs without external reducing agents, leveraging the reductive capability of the indole moiety. This FT/AuNPS nanohybrid gel enables ultrafast reductive degradation of both cationic and anionic dyes in aqueous media. For enhanced handling and practical deployment, we fabricated alginate-supported FT/AuNPs core-shell hydrogel beads, which retained structural integrity, and high catalytic efficiency, achieving more than 90% dye removal with a single 20 µL bead.[3] Altogether, this showcases the potential of single amino acid-derived self-assembled hydrogels/semicrystalline aggregates and their nanohybrids as effective, tunable, and sustainable catalytic systems for both synthetic and environmental applications.

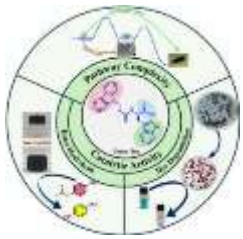


Figure 1: Schematic representation of a tryptophan-derived supramolecular hydrogel and nanocomposites for catalytic reactions and rapid dye removal.

Keywords: Supramolecular hydrogel, Pathway complexity, Gel nanocomposites, Catalysis, Water remediation

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Organic Heterostructures by Surface-Catalyzed Secondary Supramolecular Polymerization

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Over past two decades, supramolecular polymerization of π-conjugated systems have enabled the formation of nanostructures with wide variety of morphologies. However, precise modulation of supramolecular polymerization pathways via molecular design remains underdeveloped. In this study, we shift the attention from static structural motifs to dynamic systems to design circularly polarized luminescence (CPL)-active supramolecular polymers, focusing on temporally control over chirality amplification through controlled primary and secondary nucleation processes in single and two-component π-systems. We investigated the pathway complexity[1] in the self-assembly of two chiral, O-NMI-1 and O-NMI-2[2], which differ by a single methylene spacer in their ether functionality. Despite this subtle structural difference, the two systems exhibit markedly different self-assembly behavior. O-NMI-1 forms small tape-like aggregates within 1 hour that evolve into (CPL)-active nanorods over 48 hours, attributed to strong amide–amide hydrogen bonding. In contrast, O-NMI-2 forms spherical aggregates initially and transforms into helical fibers in a 1:3 MCH–decane mixture, driven by a balance of dipolar and hydrogen-bonding interactions. O-NMI-1 exhibits a complex pathway suitable for seed-induced living supramolecular polymerization, where nanorod formation occurs within 1 hour using preformed seeds, bypassing the ~48-hour lag time observed without seeding. Furthermore, hetero-seeded copolymerization using aged O-NMI-2 fibers as seeds and metastable O-NMI-1 aggregates as dormant monomers enable the formation of spatially segregated heterostructures with enhanced excited-state chiroptical properties. This is achieved via surface-catalyzed secondary nucleation and growth of O-NMI-2 nanorods from the surface of thermodynamically stable helical fibers of O-NMI-1. The coexistence of nanorods and helical fibers in aged solutions reveals a fragmentation-driven growth mechanism following secondary nucleation, providing insights into pathway-selective supramolecular polymerization.

Keywords: Self-Assembly · Supramolecular Polymers · Pathway Complexity · Living Supramolecular Polymerization · Circular Polarised Luminescence.

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Impact of Hydrogen-Bonding on the Pathway Complexity and Surface-Catalyzed Secondary Supramolecular Polymerization of π-Systems

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Achieving precise microstructural control in multicomponent supramolecular polymers is challenging due to the fast dynamics of monomer exchange, unlike their sequence-controlled covalent copolymer counterparts. As a result, the majority of reports in this area are based on examples of supramolecular copolymers, with only a handful of reports on supramolecular block copolymers."Seed"-induced living supramolecular polymerization (LSP) offers a promising strategy for constructing kinetically controlled supramolecular block copolymers and complex heterostructural topologies with controlled shapes and dimensions. In our previous study, we explored the pathway complexities of two amide-functionalized chiral dipolar NMI building blocks (**O-NMI-A** and **S-NMI-A**), which differ by a single heteroatom (-O/-S) that led to distinct self-assembly behaviors of the two building blocks in the non-polar solvent decane. Further, the hetero-seeded supramolecular polymerization between the two monomers enabled the synthesis of core-multiarmed supramolecular star block topologies via surface-catalyzed secondary nucleation.[1] We further investigated the scope of this molecular design for temporally controlled supramolecular polymerization in water from amide-functionalized NMI building block (**O-NMI-A'**) with hydrophilic oligo-oxyethylene (OE) wedges.[2] The present work highlights that subtle variations in hydrogen-bonding motifs significantly influence the pathway complexity of supramolecular polymerization in decane and showcases sequence-controlled supramolecular block copolymerization under kinetic control condition. Self-assembly of **O-NMI-U** exhibits pathway complexity. The initially formed kinetically-controlled metastable thin fibres rearrange to intermediate nanorods thatultimately evolved into thermodynamically favored chiral twisted floral nanostructures. Spectroscopic analyses revealed that multiple hydrogen-bonding interactions and stacking modes associated with the urea motif play a crucial role in directing the energy landscape of these competing self-assembly pathways. Furthermore, we uncover a remarkable correlation between molecular chirality and H-bonding interactions (amide vs. urea) in secondary nucleation events during seeded supramolecular polymerization. While homo-seeding of **O-NMI-U** followed primary nucleation-elongation mechanism, hetero-seeding between **O-NMI-A** and **O-NMI-U** triggered surface-catalyzed secondary nucleation process.[3] Detailed kinetic and microscopic analyses showed that surface-catalyzed secondary nucleation mechanisms during homochiral and heterochiral seeding experiments markedly influenced the lag phase of resulting supramolecular heterostructures and also enabled refined control over the supramolecular chirality. This work underscores the importance of secondary nucleation in achieving stereochemical and topological control in kinetically controlled supramolecular multicomponent heterostructures.

Keywords: · Pathway Complexity · Supramolecular Polymers · H-bonding · Secondary nucleation · Supramolecular heterostructures

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Dynamic Network in Polymers Based on Electrophilic-Substitution Chemistry

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Click reactions have been interesting synthetic tools for preparing functional materials with tunable properties. Among the different "Click" reactions, the electrophilic substitution (ES) reaction is an interesting synthetic strategy, especially using the derivative of the 1,2,4-triazoline derivative (TAD) as a synthon.[1,2] A Covalent ES combination of furan with TAD produces a furan-tagged triazolidine derivative that subsequently engages in hydrogen (H-) bonding with its adjacent counterpart to produce a dynamic non-covalent network, which improves mechanical properties, self-healing properties, etc.[3] Supramolecular networks formed from molecular-to-oligomeric building blocks often lack flexibility due to their stiff, crystalline, or glassy characteristics. This study unveils a simple yet effective approach to designing mechanically resilient supramolecular polymeric networks via ES click combination using oligomeric components. In this case, a series of furfuryl-capped oligomers (Mn ~200-800 Da) were synthesized and ambiently reacted with a bifunctional TAD derivative, respectively, to form supramolecular networks. The resulting cross-linked materials were obtained as free-standing, flexible films, demonstrating exceptional structural integrity. This was characterized by FT-IR, NMR, DSC and UTM analyses, which showed the presence of H-bonding in the polymers. The network based on the dimeric analogue revealed a tensile strength value of 17.45 MPa. The thermally reversible conjugates permitted these unique supramolecular materials to depolymerize and recycle multiple times. Moreover, the material exhibited excellent adhesive properties. This strategy presents a promising approach to designing high-performance materials that integrate covalent click and dynamic non-covalent chemistry, providing potential applications across various fields.

Keywords: Supramolecular polymerization, ES-Click, Bis-TAD

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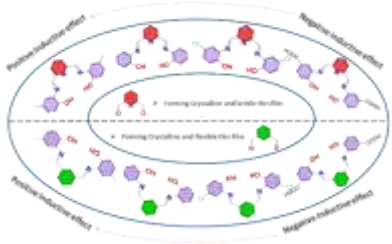
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Mechanically Robust Thin Films of Hydrogen-Bonded Supramolecular Polymers

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This study explores supramolecular polymers—dynamic, reversible materials formed by weak non-covalent interactions like π–π stacking and hydrogen bonding, which are key to structures with high mechanical strength, such as spider silk [1,2]. We focus on developing 2D supramolecular polymers with exceptional mechanical resilience and controlled topology [3]. Our design utilizes a 1,3-substituted planar motif incorporating both a rigid pyridine unit and a flexible phenyl unit. We modulated the strength of H-bonding by incorporating electronically rich and poor synthons with a controlled twist angle, successfully directing non-covalent interactions into a coherent self-assembly of supramolecular polymers yielding mechanically robust and flexible 2D thin films. These supramolecular polymers are stabilized by H-bonding, effective p-p and other non-covalent interactions, efficiently preventing the molecular slippage. The films exhibited exceptional mechanical strength (high Young's modulus), which showed a direct correlation with the electronic nature of the substituents. Furthermore, the films demonstrated selective molecular sieving, rejecting larger molecules and confirming the retention of consistent and tuneable mesh sizes [4,5].



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Anisotropic, Multifunctional Gnp/Batio3/Pi Composite Aerogels For Absorption Dominant Emi Shielding And Thermal Insulation Applications

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The increasing demand for lightweight, multifunctional materials with superior EMI shielding and thermal insulation properties has driven the development of advanced aerogel composites[1]. In this work, anisotropic polyimide composite aerogel was fabricated via an eco-friendly freeze-drying technique, using PI as the polymer matrix and GNP-BT as the hybrid filler, The unidirectional freezing process induced a unique porous morphology featuring slit-like channels and honeycomb-like structures[2,3]. The PI/GNP/BT aerogels exhibited outstanding shielding performance, achieving an average shielding effectiveness of 44.5 dB in the X-band (8.2–12.4 GHz) along the radial direction, attributed to the synergistic effect of hybrid filler incorporation and the porous structure of aerogel. The absorption-dominant shielding mechanism observed in our composite aerogels effectively minimizes secondary EM wave reflection, addressing a critical need for environmentally safe, high-performance EMI shielding materials[4,5]. Remarkably, the aerogel achieved an excellent absorption coefficient of 0.94. Additionally, the aerogel demonstrated excellent thermal insulation performance with a low thermal conductivity of 65 mW. $m^{-1}.K^{-1}$.

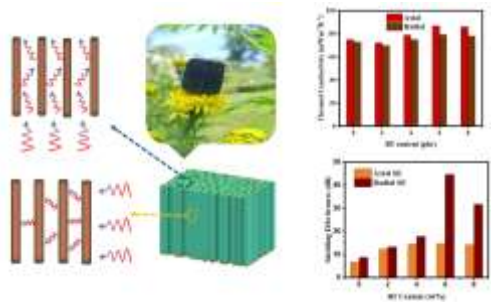


Figure 1: Anisotropy in EMI shielding and thermal conductivity of the polyimide composite aerogel.

KEYWORDS*: polyimide, barium titanate, graphene nano platelets, composite aerogel, electromagnetic interference shielding, thermal insulation.*

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Preparation and Performance Evaluation of Electrospun Oil-Absorbent Fiber Mats

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The development of advanced self-sealing coatings has gained significant attention for applications requiring rapid and efficient containment of fluid leaks, particularly in protective and barrier systems. This study explores the use of electrospun Polystyrene (PS) fibermats as highly efficient oil sorbents integrated into self-sealing coatings. Electrospinning was employed to fabricate fibermats with high surface area, and tunable porosity, and evaluating their affinity for oil uptake. Process parameters like voltage and polymer concentration and tip to collector distance was optimised to obtain uniform fibers. The morphological properties, thermal properties, and sorption capacity of prepared fibermats were evaluated using scanning electron microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), and Thermo-gravimetric Analysis (TGA) and immersion test respectively. The oil-absorption performance of the fibermats for Aviation Turbine Fuel (ATF) and Paraffin oil was characterized. The saturated absorption rate of the fibermat for Paraffin oil, ATF oil, reached approximate to 60.94 g/g and 33.06 g/g respectively. For benchmarking purposes, the oil-absorption capacity of commercial non-woven polypropylene (PP) mats and rubber samples was also evaluated. Results demonstrated that the electrospun fibermats exhibit rapid oil sorption as compared to commercially available PP fibermat and rubber sample. The pseudo-first-order and pseudo-second-order kinetic models were applied, revealing that the porosity of the fiber assemblies played a critical role in determining their oil sorption capacity.

Keywords: Polystyrene, non-woven sorbents, electrospinning, kinetics study

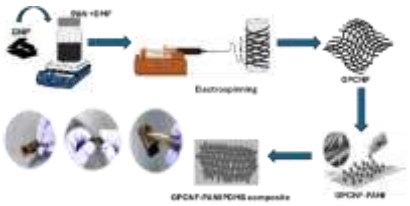
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Flexible, Ultrathin PDMS Composites Embedded with Graphene Nanoplatelets-Polyaniline Reinforced Electrospun Carbon Nanofiber Networks for Broadband EMI Shielding

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The rising prevalence of electronic devices and wireless communication systems has raised significant concerns over electromagnetic wave pollution and electromagnetic interference (EMI), which negatively affects the functioning of electronic devices, data integrity, and human health.[1] To lessen the effects of rising electromagnetic pollution, researchers have developed interest in fabricating light weight, flexible and high-performance materials which show EMI shielding capabilities[2]. In this work, we report the fabrication and characterization of polyacrylonitrile (PAN)-based electrospun carbon nanofiber (CNF) networks reinforced with graphene nanoplatelets (GNPs) and subsequently coated with conducting Polyaniline to achieve broadband EMI shielding. Graphene nanoplatelets, because to its two-dimensional architecture, exceptional electrical conductivity, and extensive specific surface area, were integrated at different loadings into PAN nanofibers using electrospinning, subsequently undergoing stabilisation and carbonisation to produce hybrid carbon nanofibers[3]. The use of GNPs boosted the graphitic structure and electrical pathways within the CNF network, while also improving interfacial polarisation and multiple reflection effects, which are essential for EMI attenuation. Subsequent surface functionalisation with intrinsically conducting polymer polyaniline (PANI), was performed to modify the electrical conductivity and dielectric characteristics of the composites[4]. The resultant flexible mats were incorporated into polydimethylsiloxane (PDMS) to create ultrathin and durable composite films, appropriate for practical electromagnetic interference (EMI) shielding applications. At a weight percentage of 7 wt% GNP, GPCNF-3 exhibited remarkable shielding efficiency of 58 dB in the X band, which rose to a peak value of 73 dB with application of 1 wt% PANI coating. Also, the ultrathin flexible composite with 0.6mm thickness showed high specific and absolute shielding effectiveness with good mechanical properties which are suitable for applications in aerospace and flexible electronics. This work provides the realization of a lightweight and flexible material which shows excellent shielding effectiveness and increased conductivity in a wide range of bandwidth(8-27GHz).



Keywords: Electromagnetic interference shielding, electrospun fiber, carbon nanofiber, polymer composites.

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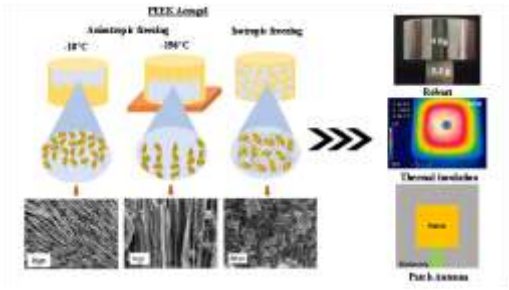
Anisotropic Polyether Ether Ketone Aerogels as Substrates for Microstrip Antennas

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The rapid advancement of space technology in recent years has intensified the exploration and utilization of space resources. As the global aerospace industry evolves, the demand for advanced thermal protection materials for aerospace vehicles continues to grow. Aerogels, with their highly porous structures and ultra-low thermal conductivity, have emerged as promising candidates for thermal insulation in such applications. Polyether ether ketone (PEEK), a high-performance thermoplastic, is renowned for its exceptional thermal stability, chemical resistance, high mechanical strength, and favorable tribological properties, surpassing most other engineering thermoplastics. In this work, we report for the first time the fabrication of porous PEEK aerogels with channel-like structures and desirable mechanical properties using a solvent-templating approach with 4-chlorophenol at two different temperatures (-18 °C and -196 °C). This strategy yielded a unique morphology with gradient porosity, imparting multifunctionality to the aerogels.

The anisotropic aerogels thus obtained were systematically compared with isotropic PEEK aerogels prepared via thermoreversible gelation in 4-chlorophenol. Notably, the optimized aerogels exhibited an ultralow dielectric constant (1.09), very low density (0.04 g/cm³, 97% porosity), and excellent compressive modulus. These attributes underscore their potential as low-dielectric substrates for lightweight antennas and as efficient thermal insulation materials in aeronautics and space applications.



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Keywords: Polyether ether ketone, unidirectional freezing, aerogels, thermoreversible gels

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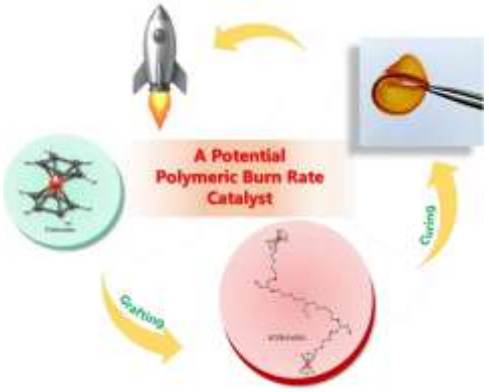
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Synthesis of novel burn rate catalyst, ferrocene polyethylene glycidyl grafted hydroxyl-terminated polybutadiene via ring-opening polymerization

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The iron content in a burn rate catalyst is a crucial factor in enhancing performance of solid rocket motor by catalyzing the ignition of propellant [**1-4**]. Present work relates to a straight forward, cost effective and industrially scalable synthetic process for a novel ferrocene-based burn rate catalyst cum polymeric binder designated as ferrocene polyethylene glycidyl hydroxyl terminated polybutadiene (HTPB-FePEG) for the AP-HTPB based solid propellant (SP) formulation. We have attached ferrocene moiety covalently at the both terminal ends of a polymeric binder named Hydroxyl terminated polybutadiene (HTPB) via ring-opening polymerization preserving hydroxyl groups at each end to allow further chemical cross-linking for polyurethane synthesis. BRCs are synthesized by altering the monomer-to-initiator ratio (M/I = 4, 10, and 20) which allow the precise control over iron content in the synthesized polymer molecule. The resulting polymers were characterized by various techniques including spectroscopic, molecular weight, Iron percentage, viscosity and thermal etc. Notably, solid propellants incorporating HTPB-FePEG with M/I ratio of 10 (HTPB-FePEG 10) shown a significantly higher burn rate, high iron content and reduced pressure index compared to propellants using unmodified HTPB. Furthermore, the synthesized polymers were successfully cured into polyurethanes (PUs), which exhibited thermal properties and glass transition temperatures comparable to those of standard HTPB-based PUs, along with excellent mechanical performance.



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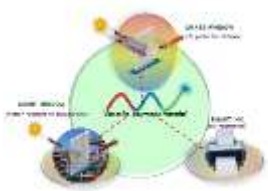
Multifunctional Polymeric Architecture as UV-Shielding Thermo-Sensor for Smart Window and Security Applications

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The development of multifunctional polymeric materials has gained significant attention due to their broad applicability in energy-efficient technologies, environmental protection, and security.1 Aerospace and defence platforms require lightweight, multifunctional polymeric coatings capable of withstanding extreme ultraviolet (UV) irradiation, rapid thermal cycling, and operational demands for secure asset identification. We report2 the design, synthesis, and performance evaluation of a coumarin-functionalized triblock copolymer, poly(methyl acrylate)100-*block*-poly(tert-butyl methacrylate)50-*block*-poly(2-(dimethylamino)ethyl methacrylate)200 (PMA100-*b*-PTBMA50-*b*-PDMAEMA200-UMB), that integrates passive thermal modulation, broadband UV attenuation, and photonic security marking within a single scalable material platform. The amphiphilic polymer exhibits a lower critical solution temperature (LCST) of ~46 °C, triggering a reversible coil-globule transition and thermally induced scattering that reduces visible light transmittance from >90% to <2%. This energy-free, switchable transparency enables autonomous thermal load regulation in spacecraft windows, optical sensor housings, and adaptive camouflage systems. UV-vis spectrophotometry confirms >99.9% blocking efficiency for UVA (320-400 nm) and UVB (280-320 nm) across operational temperatures, mitigating polymer degradation, sensor drift, and radiation-induced failures in high-altitude and space environments. Covalent incorporation of umbelliferone imparts high photoluminescence ($\lambda max \approx 455$ nm) under UVA excitation ($\lambda max = 352$ nm) while remaining invisible in the visible spectrum, enabling non-electronic, tamper-resistant tagging for defence logistics, anti-counterfeiting, and encrypted component identification. Thermogravimetric analysis demonstrates stability up to ~240 °C before decomposition, and repeated thermal cycling confirms retention of optical and structural performance. The copolymer's solution processability allows conformal deposition on diverse aerospace-grade substrates via spray, dip, or spin-coating, supporting integration into large-area or complex geometries. By synergistically combining radiation shielding, thermal adaptivity, and secure photonic encoding, PMA100-*b*-PTBMA50-*b*-PDMAEMA200-UMB advances multifunctional coating technology for aerospace and defence theatres, with potential deployment in orbital vehicles, visor optics, and strategic infrastructure protection.

Keywords: Thermoresponsive polymers, UV-shielding coatings, Aerospace materials, Defence security marking, Smart window.



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Lightweight PVDF-HGM-MWCNT Syntactic Foams with Enhanced Absorption-Dominant EMI Shielding Performance

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Lightweight syntactic foam composites based on poly-(vinylidene fluoride) (PVDF), hollow glass microspheres (HGM), and multi-walled carbon nanotubes (MWCNT) were developed via a facile solution casting approach for enhanced electromagnetic interference (EMI) shielding performance. The incorporation of HGM not only reduces density but also promotes the uniform dispersion of MWCNT within the PVDF matrix, facilitating the formation of interconnected conductive networks. This structure enhances electrical conductivity and promotes multiple internal reflections, contributing significantly to EMI shielding through absorption mechanisms. The prepared composites exhibited excellent EMI shielding effectiveness (EMI SE) in the X-band (8.2–12.4 GHz), achieving up to 29.75 dB at 14 wt% MWCNT with a thickness of 1.6 mm. Morphological analysis confirmed uniform distribution of MWCNT and HGM, while XRD and FTIR analyses revealed enhanced β-phase crystallinity in PVDF, further supporting improved electrical properties. The absorption-dominant shielding mechanism was validated by the breakdown of total EMI SE into reflection and absorption contributions, with absorption accounting for the majority of shielding performance. These lightweight syntactic foams present a promising pathway for developing advanced EMI shielding materials for aerospace, electronics, and communication applications.

Keywords: PVDF-HGM-MWCNT, Syntactic Foam, Lightweight Composite, EMI Shielding, Absorption Mechanism

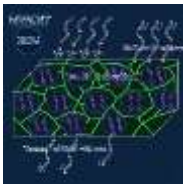


Table 1 shows the EMI Shielding Effectiveness and Electrical Conductivity of PVDF-HGM-MWCNT Syntactic Foam at Different MWCNT Loadings and EMI-SE mechanism in the figure above.

MWCNT Loading (wt%)	Electrical Conductivity (S/cm)	Total EMI SE (dB)
5	0.12	20.35
8	0.70	24.92
12	2.50	27.06
14	5.00	29.75

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Computational Insights into Gel Polymer Electrolytes for Advanced Energy Storage Applications

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Gel Polymer Electrolyte (GPEs) have gained significant attention for their potential applications in next-generation energy storage devices, such as Lithium-ion batteries and Supercapacitors. These materials combine the properties of solid polymers and liquid electrolytes, offering improved safety, flexibility, and performance. In this study, we are aiming to explore the molecular-level interactions and properties of GPEs through computational methods, focusing on a system comprising polymer, ionic liquid, and a salt. The selected materials should be selected on the basis of their potential in forming stable, high-performing electrolytes. The goal of this research is to gain insights into structural and dynamic properties of the GPE at the molecular level using molecular dynamics simulation. The Study will explore key parameters, such as the Radius of Gyration (R_g), Solvent-accessible surface area (SASA), Diffusion coefficients, ionic conductivity, Radial distribution function (RDF), and Mean-Square Displacement (MSD), to better understand the relationship between polymer architecture and ionic transport properties. These calculations will provide valuable insights into the interplay between polymer chain flexibility, ion movement, and electrolyte performance.

In the future, this computational approach will aid in the design and optimization of GPEs, helping to fine-tune the composition of polymers, ionic liquids, and salts for enhanced electrochemical performance. The findings are expected to give us an important perspective on the internal workings of polymer electrolytes and help us in further studies and experimental validation of the gel polymer electrolytes.[1][2]

Keywords : Gel Polymer Electrolytes, Batteries, Radius of Gyration, Electrolytes

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Molecular Simulations Studies of phase transition behavior of stimuli responsive polymers in solutions

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This investigation explores the phase behaviour of thermoresponsive polymers in aqueous solutions, focusing specifically on their coil-to-globule conformational transitions to determine the lower critical solution temperature (LCST) which is an essential factor for biomedical in pivot role. Thermoresponsive polymers exhibit reversible alterations in solubility in response to external stimuli such as temperature. The LCST signifies the temperature at which the polymer undergoes a clear transition from a hydrophilic, expanded coil state to a hydrophobic, compact globule. Due to their temperature-triggered nature, thermoresponsive polymers are useful in drug delivery, tissue engineering, and biosensing. Their LCST, at 32 °C, matches human temperature, allowing for precise material response control. Minimally invasive hydrogel wound healing and localized therapeutic applications benefit from this characteristic. In this study, we are aiming to investigate the molecular-level interactions and properties of Thermoresponsive polymers influencing LCST behaviour. The study will explore the key parameters, such as radius of gyration, solvent-accessible surface area, and intra-intermolecular hydrogen bonds are analysed to assess the coil-to-globule transition and determine how the polymer's environment influences its behaviour. Although the findings remain preliminary, first trends indicate a clear sensitivity of polymer structure to temperature and solvent conditions. This underscores the promise of simulation-based frameworks for the development of ecologically friendly, stimuli-responsive polymer systems. These approaches enhance our ability to predict and optimize material responses for advanced biological applications, offering a pathway to precise, adaptable, and less invasive therapeutic interventions.[1]

Keywords: Thermoresponsive polymer, LCST, phase transition

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The Thermophysical Properties and Molecular Interactions Mechanism of pure IL, ([EMIM][SCN]) in Binary Mixtures: Insights form experiment and computation

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In this project, thermophysical properties such that densities **(ρ)**, sounds velocities, **(u)** and dynamic viscosities, **(η)** for both pure, IL 1-ethyl-3-methylimidazolium thiocyanate [EMIM][SCN] and 2-methoxyethanol (2-MEOH) and 1-Pentanol (1-POH) solvent, and their binary mixture ([EMIM][$EtSO_4$]) + 2-MEOH and ([EMIM][$EtSO_4$]) + 1-POH have been measured in temperature range from 298.15 K to 323.15 K under 1 atm pressure. These tasks bound by the aim, how organic solvent concentration governing the thermophysical properties of the binary mixtures. For gaining insight into the interaction mechanisms and alteration form ideal mixing behaviour, these properties, i.e. Excess molar Volumes (V^E), isentropic compressibilities deviations, ($\Delta\kappa_s$) and dynamic viscosities deviations, ($\Delta\eta$), have been calculated. Further, the derived parameters have been fitted to the Redlich-Kister equation which yielding standard deviations (σ), fitting parameters (A_i) and correlation coefficients (R^2) which collectively justified the quality the of experimental data. The application of Prigogine-Flory-Patterson (PFP) theory facilitates the assessment of possible interactions and excess volumetric behaviour in binary mixture. Density Functional Theory (DFT) performed for both pure and binary mixture that gives the important parameters, like HOMO-LUMO energy gap, reduced density gradient (RDG), non-covalent interaction (NCI) analysis, molecular electrostatic potential (MEP) maps, global reactivity descriptors which explain the interaction occurring in both systems. All these parameters combinedly explain the strength and nature of innervations in theses system. In addition, Furthermore, molecular dynamic (MD) simulations has been conducted for both pure and their binary mixture to gain atomic and the molecular level insights. These study gives the data of density, radial distribution function (RDF), coordination number, along other dynamical properties such as mean square displacement (MSD), and self-diffusion coefficient (SDF) [1-4].

Keywords: Ionic Liquid, Binary Mixtures, Thermophysical Proeprteis, Excess Molar Volume, Denisty Fucntional Theroy (DFT), Molecular Dynamic (MD) simulation.

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CONCENTRATION- AND SUBSTRATE-DRIVEN PATTERN FORMATION IN EVAPORATING POLYSTYRENE–TOLUENE DROPLETS

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The evaporation of polymer solution droplets plays a central role in technologies such as inkjet printing, diagnostic assays, particle templating, and thin-film fabrication [1]. Pattern formation during drying depends strongly on polymer concentration, solution rheology, and substrate properties [2]. In this study, we investigate the drying behavior of polystyrene (PS)–toluene solutions (0.25–1.0 wt./vol.%) on bare and silanized glass substrates. Using optical microscopy at multiple scales, we correlate polymer concentration with deposition morphology. At low concentration (0.25%), low viscosity and high chain mobility prevent effective contact line pinning, resulting in nearly uniform thin films dominated by diffusion. At 0.50%, a transitional regime appears, where weak coffee rings coexist with central deposition, reflecting a balance between diffusion and flow effects as viscosity and polymer interactions increase. At 0.75%, chain entanglements enhance rheological resistance and contact line pinning, producing pronounced coffee-ring patterns. At 1.0%, complex morphologies emerge due to competing instabilities, strong pinning, and earlystage dewetting, highlighting the dominant role of concentration-enhanced rheology. Substrate wettability also influences deposition: silanized glass, with reduced surface energy, promotes dewetting at high concentrations, while bare glass favors more uniform spreading [3]. These observations demonstrate the coupled effects of polymer concentration and substrate chemistry on evaporative self-assembly and pattern formation. Understanding these concentration-dependent transitions can guide the control of non-uniform deposits in printing and coating technologies, especially where precise patterning or uniform thickness is needed. Beyond practical applications, the results provide insight into contact line physics and nonequilibrium pattern formation. Future work will include quantitative mapping of film thickness and time-resolved imaging of pinning–depinning events to develop predictive scaling laws for drying dynamics across different surfaces.

Keywords: Polymer solution evaporation, Contact line pinning, Coffee-ring effect, Substrate wettability, Pattern formation.

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SOLVENT PENETRATION – DESORPTION MEDIATED MORPHOLOGY TRANSFORMATION IN A CROSS-LINKED ELASTOMERIC FILM

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Wrinkles appear on soft substrates across scales from the macroscopic to the nanoscale and can be created using various physical and chemical techniques. Physical methods include thermal, mechanical, capillary, and osmotic stresses, while chemical approaches involve oxygen plasma, UVO treatment, or corona discharge. These controllable and tunable wrinkle patterns are useful in electronics, optics, adhesives, and other applications, with PDMS being a preferred material due to its optical clarity, ease of patterning, gas permeability, thermal stability, and biocompatibility[1]. Thin films of Sylgard 184, a thermo-curable cross-linked PDMS elastomer, were fabricated via spin coating a mixture of part A oligomer (vinyl-terminated siloxanes) and part B curing agent (dimethyl, methyl hydrogen siloxane) in a 10:1 ratio, diluted with n-hexane (1:10), on glass substrates. Complete crosslinking was achieved by heating at 120 °C for 24 h, producing films of 3–4 µm thickness with a water contact angle of ~108°.The morphological evolution of the films under solvent exposure was studied using optical microscopy. Upon exposure to organic solvent vapor, solvent molecules diffused into the PDMS matrix, inducing surface patterning; removal from the vapor environment restored the initial morphology as solvents diffused out. Wrinkling arises from selective swelling of the film's top layer while the bottom remains constrained by the rigid substrate [2]. This gradient generates anisotropic osmotic pressure, leading to compressive stress that exceeds a critical threshold, causing buckling and periodic wrinkle formation. The swelling and resulting wrinkle morphology depend on the solvent's solubility parameter relative to PDMS (~7.3 cal ½ $cm^{-3/2}$) [3]. Solvents such as n-hexane, chloroform, ether, and xylene, with solubility parameters between 7.3–9.5, exhibit high compatibility, producing pronounced surface patterns. N-hexane was selected for controlled experiments due to its moderate solubility, allowing observable morphological changes over extended durations. These findings demonstrate that solvent-polymer interactions in cross-linked PDMS govern swelling-induced surface instabilities. The study provides a framework for tuning wrinkle wavelength and amplitude via solvent selection, relevant to applications in soft material engineering, surface patterning, and endodontic retreatment, where controlled swelling of PDMS by organic solvents is critical. Overall, the study advances understanding of solvent-induced swelling in PDMS and highlights its importance for coatings, and soft-material interfaces.

Keywords: Cross-linked PDMS Thin Films, Solvent-Induced Swelling, Wrinkling Instability

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Controlled Plasma Oxidation Driven Wrinkling of PDMS for Scalable Soft Surface Patterning

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Controlled surface morphologies on soft polymers are vital for tailoring interfaces in microfluidics, optics, sensors, and flexible electronics[1-4]. This study examines the formation and tunability of plasma-induced wrinkle patterns on uncross-linked and crosslinked polydimethylsiloxane (PDMS) thin films. Oxygen plasma treatment converts the PDMS surface into a thin, stiff silica-like (SiOx) layer atop a compliant substrate, forming a mechanically heterogeneous bilayer. The elastic mismatch generates compressive stress during cooling, inducing buckling instabilities that create ordered wrinkle morphologies. Wrinkle evolution was observed by optical microscopy, while atomic force microscopy (AFM) quantified wavelength and amplitude. AFM scans (Figure 1) reveal a clear reduction in wrinkle wavelength with increasing PDMS precuring time (0–30 min), attributed to enhanced stiffness and reduced oxidation depth. Wrinkle dimensions depend strongly on plasma exposure and precuring conditions: prolonged plasma treatment increases the oxidized layer thickness and modulus contrast, whereas shorter exposures and secondary treatments such as thermal annealing or repeated plasma pulses yield finer wrinkle patterns. This metal-free, scalable, and lithography-independent process provides precise control of nanoscale textures through simple parameters, offering insight into interfacial stress evolution and a route to adaptive soft surfaces with tunable wettability, adhesion, and optical functionality.

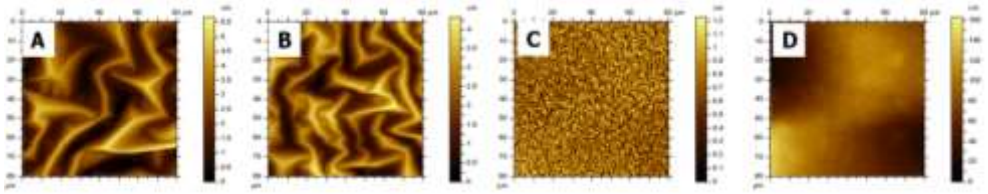


Figure 1: Evolution of wrinkle morphology observed via AFM as a function of PDMS precuring time, illustrating the decrease in wrinkle wavelength, (a) 0 min, (b) 5 min, (c) 10 min, and (d) 30 min.

Keywords: Compressive stress, Precuring time, Thermal annealing, Stress relaxation.

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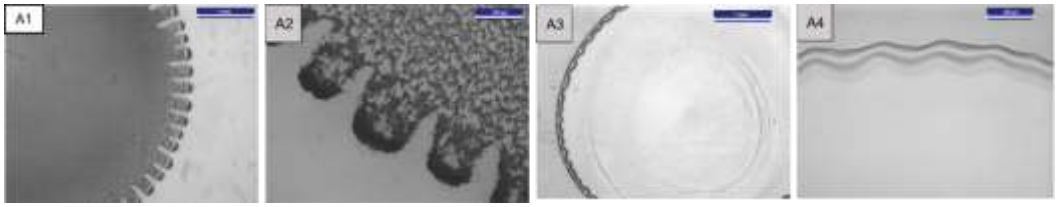
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UNIQUE CONTACT LINE DYNAMICS IN EVAPORATIVE DRYING OF A POLYMER SOLUTION DROP IN A HIGH VOLATILITY SOLVENT

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Evaporative drying of a polymer solution droplet is well investigated and often leads to unique non-intuitive deposition patterns that may include deposition of a thick peripheral deposit known as the coffee ring [1]. The radially outward flow of the solute molecules is attributed to finite pinning of the contact line leading to stick slip motion and combined effects of thermo capillary flow, solutal Marangoni flow [2]. The ring deposit often comprises of periodic undulations, which is attributed to Bernard convection cells active along the contact line. In this work we report the evaporative drying of a droplet of a dilute solution of Polystyrene (PS) in highly volatile solvent Tetrahydrofuran (THF). The observed pattern formation reveals elongated periodic finger-like structures along the droplet periphery, accompanied by signature broken polymer threads covering the initial footprint of the dispensed droplet. The rapid evaporation of the solvent establishes a strong radial concentration gradient from centre to periphery. The dominance of the solutal Marangoni force manifests in the robust growth of fingers along the droplet's periphery. The undulations, resembling elongated periodic fingers, are attributed to Bernard convection, while the solutal Marangoni flow from the centre to the periphery contributes to their elongation. The central region of the droplet is enveloped by the polymer, yet the swift solvent evaporation concurrently gives rise to ruptured threads. At higher polymer concentrations, the increased viscosity and chain entanglement suppress the surface-tension-driven instabilities, leading to more continuous and uniform polymer films. These findings demonstrate that the interplay between solutal Marangoni convection, solvent volatility, and concentration-dependent rheology dictates the final deposit morphology. This research advances our understanding of contact line dynamics in polymer solution drying, providing insights into the intricate interplay of various forces and their impact on pattern formation.



Figures: Optical microscope images of patterns obtained after evaporation of Polystyrene solution droplet (A1:A2) 0.5w/v% PS/THF (A3:A4) (High evaporating solvent) 0.5 w/v% PS/Toluene (Low evaporating solvent).

Keywords: Evaporative Drying, Coffee ring effect, Solutal Marangoni Flow, Thermal Capillary flow

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Texture Evolution of 5CB Thin Films under Thermal Cycling and Room Temperature Aging

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Nematic liquid crystals phases are highly responsive to change in the electric and magnetic fields causing them to reorient thereby modulating the optical and electro-optical properties of the material.[1] This characteristic provides the foundation for the majority of liquid crystal displays (LCDs), which control the flow of light via polarizing filters to produce images by applying tiny voltages across thin layers of nematic liquid crystal.[2] Nematic phases also exhibit topological defects, such as disclinations due to the interaction of the liquid crystal molecules with the polar molecules of the substrate on which they are coated, which are points or lines where the molecular orientation is undefined.[3,4] These defects are visible under polarized light microscopy as characteristic dark lines or brush-like textures (e.g., schlieren patterns) that originate from a point called disclination point or point singularity. The behavior of these defects and their response to external stimuli like change in temperature, electric, magnetic fields is not only important for understanding fundamental physics but also for technological applications where defect control is crucial for display quality and device performance.[5]

The morphology of 4′-pentyl-4-biphenylcarbonitrile (5CB) liquid crystal thin films on poly (methyl methacrylate) (PMMA) substrates was investigated under thermal phase transition cycling and room temperature aging. PMMA in toluene was spin coated on silicon wafers (1.5 *1.5 cm) (hPMMA = 543.64 ± 6.9 nm) and annealed at 60°C. The PMMA thin film was used as a substrate to deposit uniform 5CB thin film by spin coating from ethanol (h5CB = 150.2 ± 1.7 nm). Optical microscopy under cross-polarized light was used to analyse film morphology. Repeated heating–cooling cycles revealed progressive changes in texture, quantified through disclination point density measurements. Additionally, long-term ambient aging led to gradual modifications in the nematic texture. These findings highlight the sensitivity of 5CB thin-film morphology to both thermal cycling and environmental stability, offering insights into liquid crystal anchoring behavior on polymeric substrates.

Keywords: Liquid crystal, Nematic, Phase transition, Disclination point density, Thin films

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Influence of Gel Solvent on the Crystal Structure and Crystalline Orientation in Anisotropic Nylon 11 Aerogels

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The tailored modification of crystalline structures in Nylon 11 (PA11) aerogels is essential for enabling diverse applications, including energy harvesting, thermal management, and acoustic insulation. PA11 can crystallize into several polymorphic forms (α, α′, β, γ, δ, and δ′), each imparting distinct properties to the material. By selecting appropriate solvents and employing freeze-drying techniques, these crystalline phases can be tuned in aerogels through solvent–polymer interactions. In this study, thermoreversible gels and aerogels of PA11 were prepared using two solvents, formic acid[1] and N,N-dimethylformamide (DMF), to investigate how solvent–polymer interactions influence gelation, crystal structure, morphology, and porosity. Solvent-induced gelation produced three-dimensional networks that, after solvent exchange and freeze-drying, yielded lightweight, highly porous aerogels. Although PVDF aerogels in their *α*, *β*, and *γ* crystalline forms through a precise selection of solvents have previously been reported,[2] this is the first observation of such behavior in PA11, particularly noteworthy given the limited number of solvents available for this polymer. Our findings demonstrate that both crystallinity and polymorphic transitions are strongly solvent-dependent, as solvent-polymer interactions modulate PA11 chain conformations. Wide-angle X-ray diffraction confirmed the coexistence of α and γ crystalline phases in formic acid-induced PA11 gels and aerogels, along with crystal orientation in anisotropic samples. In contrast, DMF-induced gels and aerogels crystallized exclusively in the α form, without orientation. The resulting aerogels display varied morphologies, as well as distinct mechanical, thermal, hydrophobic, and acoustic properties, depending on their crystalline structure. At the same time, all fabricated aerogels share the advantageous characteristics of low density, high porosity, and light weight, positioning them as promising candidates for multifunctional applications.

Keywords: Nylon 11, thermoreversible gel, aerogel, crystalline forms

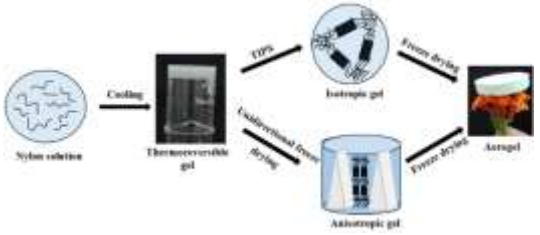


Figure. Fabrication process of isotropic and anisotropic Nylon 11 aerogels

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Polylactide Stereocomplexation in Melt-Quenched Block Copolymer Blends: Structural Evolution During Triblock Terpolymer Formation

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Understanding the structural development and stereocomplex (SC) formation in polylactide (PLA)-based block copolymer systems has garnered significant interest for tailoring material properties and expanding potential applications.[1-3] In this study, we investigate the structural and morphological evolution of melt-quenched diblock copolymers, poly(isoprene-b-L-lactide) (PI-b-PLLA) and poly(styrene-b-D-lactide) (PS-b-PDLA), along with their non-covalent triblock terpolymer blends during controlled heating. For PI-b-PLLA, fractional crystallization of the PLLA block occurs under soft confinement. Specifically: (i) PLLA initially crystallizes into metastable β and forms, which subsequently transform into the stable form; (ii) persistent microphase separation is observed between 70–110 °C, accompanied by significant thickening of microdomains; and (iii) above 110 °C, breakout crystallization indicates a transition beyond the soft confinement regime.[2] In PS-b-PDLA, the PDLA block crystallizes directly into the α form under hard confinement, constrained by the microphase-separated morphology. In melt-quenched blends, PLA crystallizes just above the glass transition temperature into the SC form, along with metastable intermediates such as the SC mesophase, , and forms, which gradually evolve into the stable SC structure. Microphase separation is retained below 110 °C, while breakout crystallization above this temperature signifies the breakdown of confinement. These findings shed light on the confined crystallization behavior and SC formation pathways in PLA-based block copolymers, offering valuable insights for the design of high-performance biodegradable materials.

Keywords: Polylactide, stereocomplex, crystallization, phase separation, block copolymer

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Development of a resin system suitable for the Resin Film Infusion process and high thermal stability.

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Advanced composite materials with high specific strength, along with thermal stability and reliable structural properties, are always in high demand in aerospace, military, electronic, and space applications. In this study, Bisphenol A based Dicyanate ester (BADCy) resin were developed with an aim of having a high glass transition temperature of more than 350 ^{0}C, suitable for an out-of-autoclave (O-O-A) composite manufacturing process called Resin Film Infusion (RFI).[1,2]
This article demonstrates a systematic scientific approach to optimize rheology and tackiness, both of which are important RFI process parameters. In order to ensure complete and homogeneous mixing, the resulting blends were prepared using a vacuum-assisted planetary mixer. Thermal properties assessed through DSC and TGA provided important insights into the chemical and physical stability of the blends at elevated temperatures above 350 ^{0}C. Additionally, the blends demonstrated reliable behavior under extreme thermal stress, confirming their potential for high-temperature composite applications in engineering fields. [3,4]

***Keywords**:* cyanate ester; thermoset; polymer blend; Polymer processing;

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Rheological Characterization of Graphene Reinforced Epoxy for Resin Film Infusion

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Since its discovery in 2004, graphene is considered as the mother of all graphitic materials. Graphene finds vast applications in electronics, energy, biomedical and composite industries. Being the strongest and toughest material ever discovered, graphene is an appropriate nano-filler to be used as reinforcement in a polymer resin. It aids in improved mechanical, electrical and thermal properties of host material. In this investigation, graphene has been incorporated to an in-house developed epoxy formulation at a low loading fraction. A solvent-free ultra-sonication assisted process ensures thorough dispersion of nano-filler in the resin. The Diglycidyl Ether of Bisphenol A (DGEBA) based epoxy formulation is based on certain viscosity requirements so as to form a film with appropriate tackiness at ambient conditions. These films would be sandwiched between continuous fibers followed by a standard vacuum bagging process under controlled thermal cycles to fabricate composite laminates with high volume fraction and near zero void content through a process called Resin Film Infusion (RFI). Incorporation of nano-filler in a low loading fraction shall not affect the viscosity profile and related processing conditions through RFI.

Extensive rheological evaluation of graphene reinforced epoxy formulation has been carried out in this study and the data has been compared with the control resin processed under identical conditions but without graphene. Viscosity of the resin was evaluated over a temperature range of 60-90°C at three different shear rates using a parallel plate geometry. As expected, higher shear rates consistently resulted in lower viscosity. Additionally, viscosity was monitored over time under isothermal conditions between 80-100 °C. A sharp rise in viscosity after a certain period indicated the onset of curing. To determine gel time, storage and loss moduli were plotted against time at different temperatures. The crossover point, where the storage modulus overtakes the loss modulus, was considered as the gel point. The corresponding gel times at each temperature were used to calculate the activation energy of curing using Arrhenius equation. The data offers significant insights in optimizing the temperature, time and other processing conditions for composite manufacturing through RFI.

Keywords: graphene, epoxy, viscosity, gel time, RFI

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Tunable Crosslinking Density in a Polyurethane based Nanonetwork: A Leakage free Nanovehicle for Cocktail Drug Delivery to Cancer Cell

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We reported an amphiphilic polyurethane integrated with tertiary amine group on the backbone and pyridyl disulfide group as a pendant. In water, the polymer self-assembles into nanoaggregate via entropy driven process. To stabilize the drug molecules inside the nanoaggregate, a crosslinked nanonetwork was fabricated by thiol-disulfide exchange reaction to generate multiple disulfide bonds, which degrades in the redox environment of cancer cells, thus enables sustained release of anticancer drugs in the cytoplasm. The cancer cell selective cellular uptake arises due to the positive surface charge generation at tumor extracellular matrix relevant pH. The nanonetwork showed very minimum drug leakiness as indicated by low leakage coefficient and only ~3% drug release in absence of redox environment. The biological evaluation revealed cancer cell selective cellular uptake and significant cell death in HeLa and MDAMB-231 cells upon treatment with nanonetwork@DOX, and shielding effect in normal cells from off-target toxicity. The combined drug therapy against cancer cell showed higher % of cell death with lessor IC50 value. Thus, the ease of nanonetwork fabrication, enhanced tumoral cell uptake, redox responsive drug release, synergistic effects of combined drug therapy, we believe, will make this system a leak proof delivery vehicle for combination drug therapy in cancer.

Keywords: Polyurethane nanonetwork, crosslinked disulfide core, surface charge modulation, drug cocktail, cancer cell selective delivery

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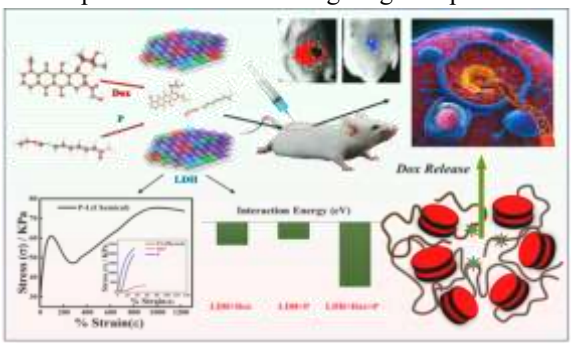
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Mechanically Responsive Organic-Inorganic Hybrid as Advanced Delivery Vehicle for Targeted Cancer Treatment

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Clinical oncology faces a persistent challenge as tumors rapidly evolve therapy resistance, undermining conventional treatments. Chemotherapy, though effective in inducing cancer cell death, is often compromised by intrinsic cellular defenses, highlighting the urgency for precision-controlled strategies. Here, we present a tumor-targeted drug delivery system developed through interlamellar surface modification of hydroxyl groups in pristine Li - Al layered double hydroxide (LDH) [1]. Grafting polyurethane (PU/P) onto LDH significantly enhances mechanical resilience, achieving an extraordinary elongation at break of 1230%. Such flexibility ensures adaptability within dynamic physiological environments, vital for injectable and implantable carriers navigating complex tissue architectures. These fully biodegradable nanohybrids are engineered for sustained release of doxorubicin (Dox), where the PU prepolymer graft fine-tunes the hydrophilic - hydrophobic balance, enabling synchronized drug delivery [2]. First-principle density functional theory (DFT) analyses elucidate molecular interactions between Dox and the nanohybrid, supporting its role as an advanced carrier. In vitro and in vivo studies, particularly in luciferase-expressing melanoma-bearing mice, confirm remarkable biocompatibility and synergistic anticancer efficacy. Moreover, an injectable hydrogel [3] beneath the tumor site mitigates systemic toxicity by precisely regulating drug release. This pioneering platform introduces a multifunctional nanomedicine, advancing precision, stability, and patient safety in next-generation cancer therapies.



Keywords: Layered Double Hydroxide; Polyurethane; Mechanically Responsive; Controlled Drug Release; Targeted Cancer Treatment.

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Morpholinone-Based Multi Stimuli Responsive Polymer Architecture for Sequential receptor and Mitochondrial Targeting in Orthotopic Breast Cancer Therapy: Integrating Synergistic Chemo-Photodynamic Effect

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The chemotherapeutic efficacy and consumption of complexity on healthy cells and tissues become one of the major objective for the treatment of cancer. Toward serve our goal, we developed a biodegradable, highly water soluble, multi stimuli responsive (esterase, pH, GSH) theranostic polymer GPB+NIR that was affixed with dual chemotherapeutic agent (gemcitabine and bortezomib), receptor targeting agent (biotin), a cationic charged near-infrared (NIR) fluorescence dye for mitochondriotropic agent and bio imaging purpose[1]. Our expectation is that the polymer will self-assemble and penetrate the endothelial membrane via EPR effect and enter in to cancer tissues by the process of avidin mediated endocytosis. Our strategy is taking favour of overexpressed esterase, low pH and the high glutathione (GSH) concentration in cancer cells, the ester bond will be cleave and disulfide bond will reduce in GPB+NIR respectively. As a consequence active anticancer drugs will release and a near-infrared (NIR) fluorescence dye will turn-on[2]. The proteasome inhibitor bortezomib will induce apoptosis and also enhance the efficacy of gemcitabine. Our glory of this project the drug delivery vehicle is newly synthesized backbone that having combination effect of bortezomib and gemcitabine will enhance the activities against the orthotopic breast cancer therapy.

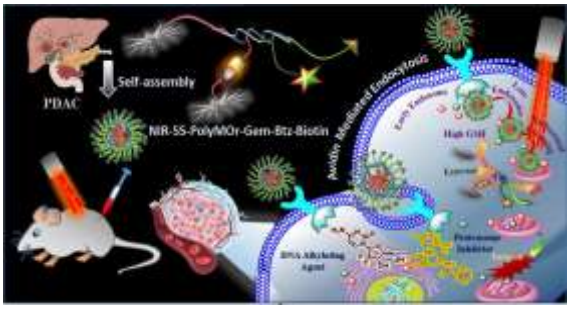


Figure1: Biodegradable multi-stimuli responsive polymer, sequential receptor and mitochondrial targeting synergistic chemo-photodynamic.

Keywords: Biodegradable, Multi-stimuli responsive, Biotin receptor-Mitochondrial dual targeting, Orthotopic breast cancer, Synergestic chemo-photodynamic effect.

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Development of Biopolymer hydrogel with natural nanoclay for wound healing

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Wound healing is a complex process that involves hemostasis, inflammation, proliferation, and remodeling of the damaged tissue. In the study, a biodegradable polymer hydrogel has been developed by incorporating nanoclay which is abundantly present in Rajasthan, having wound-healing potential. Its physicochemical, biocompatibility, anti-bacterial, and wound healing properties have been investigated through in vitro and in vivo experiments. The in vitro anti bacterial assay with S. aureus and E. coli has confirmed its antibacterial effectiveness. The in vitro biocompatibility and cytotoxicity of the formulated hydrogel were evaluated using the NIH-3T3 cell line, which reveals that the gel is biocompatible and shows no toxicity towards cells up to 3 days. The hydrogel has shown accelerated wound closure within 13 days in contrast to 23 days for the control group. The clinical trial studies (disbudding experiment) on large animals also demonstrated promising results showing rapid healing of wounds compared to conventional medicine The results suggest that the biodegradable gel comprising the natural nanoclay is a promising alternative for wound healing. Electrospun scaffolds can also be used for wound healing by the use of natural nanoclay.

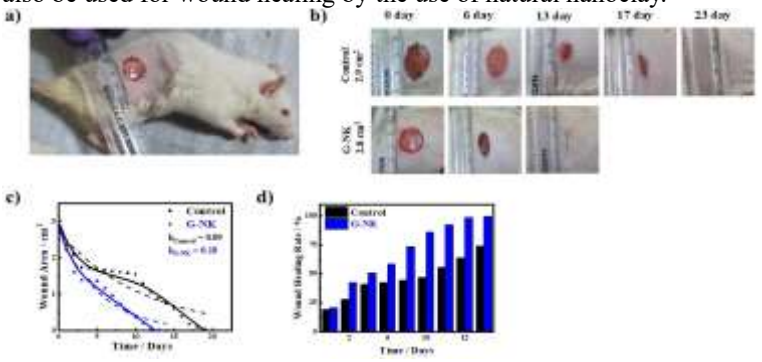


Fig. In vivo wound healing using albino rat model. b) Representative images of healing of wound for control and G-NK hydrogels with time, b) Plot of wound area with time for control and G-NK hydrogel, c) Plot of wound healing rate with time for control and GNK hydrogel.

Keywords: Nano clay, hydrogel, biodegradable polymer, wound healing.

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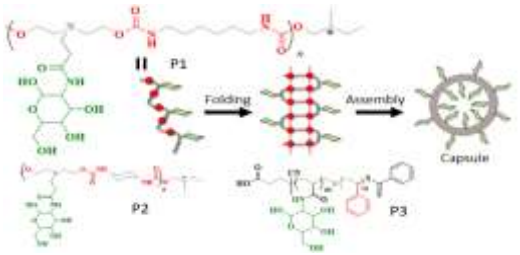
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Surface Functional Group Display in Chain-Folding Regulated Assembly of Amphiphilic Polyurethane

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Multivalent binding plays important role in many biological processes. Synthetic self-assembled biomaterials also often reply on multivalent binding with biological targets for specific functions and for this it is imperative to have efficient display of functional groups on the surface of different self-assembled structures. In the recent past, we have introduced chain-folding regulated assembly of amphiphilic alternating copolymers based on the polyurethane backbone.[1] Intra-chain H-bonding stabilized folding, followed by hierarchical assembly leads to uni-lamellar polymersome/capsule (Figure 1). In such structures, 50 % of the appended hydrophilic groups should be displayed at the outer surface, which could be significantly higher and highly beneficial, when compared to amphiphilic block copolymers in which only the terminal groups, present in the end of the hydrophilic block, are displayed at the surface. To test such possibilities P1 (Figure 1) was synthesized with appended carbohydrate groups, known to exhibit multivalent binding with ConA, a protein. It showed spontaneous capsule like morphology with the ability to sequester hydrophilic guest molecules in its water-filled lacuna. Surface-displayed carbohydrate groups were estimated by glucose oxidase peroxidase (GOD-POD) assay that indeed showed ~ 50 % surface (outer) functional group display. This resulted in excellent multivalent binding with ConA (K_a ~ 6 x 10^4) as estimated by the ITC technique. a control polymer (P2, Figure 1), deprived of such chain-folding possibility due to the rigid backbone, showed negligible multivalent binding with ConA, confirming the unique structure and function of P1 originate from its chain-folding regulated well-defined assembly. Interestingly the amphiphilic block copolymer P3 (Scheme 1) also did not show any glycol-cluster effect under similar condition unlike P1, indicating much superior functional group display and multivalent binding ability of P1, owing to the unique chain-folding regulated assembly of P1.



Figures 1 – Structures the polymers and schematic showing possible chain-folding regulated assembly of P1.

Keywords: Glycopolymer, chain folding, self-assembly, surface group display, bacterial adhesion.

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Biocompatible Croton bonplandianum extract-based PVA/Graphene oxide electrospun nanofibrous scaffolds for fast wound healing.

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Wounds are a major public health issue due to their prevalence [1-2] and treatment costs. Reactive oxygen species (ROS) aid physiological wound healing. Maintaining ROS levels between high and low is important. Innovative[3-5] treatment strategies focus on antioxidant dressings regulating this equilibrium. We created electrospun nanofibrous scaffolds using Croton bonplandianum extract (CBE) and graphene oxide. The 2,2-diphenyl-1-picrylhydrazyl (DPPH) experiment showed antioxidant activity in the scaffolds. By adding GO, the scaffolds became antibacterial against Gram-positive and Gram-negative bacteria. Scaffolds 3 reduced viable E. coli and S. aureus cells by 78% and 85%, respectively, after 1 h. Biocompatibility and hemocompatibility were good. Scaffolds also enhanced wound healing in rats in 12 days. H&E-stained skin samples from rats treated with the scaffold showed increased epidermis and hair follicle growth, suggesting re-epithelialization. Thus, CBE-infused nanofibrous scaffolds offer a new wound healing therapy.

Keywords: Electrospun nanofiber, Antioxidant dressings, Croton bonplandianum,In-vivo wound healing.

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Reducing Agent-Triggered Templated Formation of Dynamic Covalent Poly(disulfide) Nanonetworks Enabling Precise Control over Encapsulation and Release Behavior

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In recent years, crosslinked nanocarriers have attracted significant attention as next-generation drug delivery systems due to their ability to overcome the intrinsic limitations of conventional self-assembled nanostructures such as micelles, vesicles, and liposomes. While traditional assemblies suffer from premature disassembly, drug leakage, and poor stability under physiological dilution, covalent core crosslinking offers an effective strategy to lock the nanoarchitecture, thereby improving structural integrity, drug encapsulation stability, and controlled release performance.

Here, we report a templated synthesis strategy to develop a dynamic covalent crosslinked poly(disulfide)s-based nanonetwork derived from biomass-sourced lipoic acid amphiphiles. Crosslinking was triggered in aqueous medium at room temperature by simply treating preformed nanoaggregates (~130 nm, DLS) with a reducing agent. By tuning the monomer-to-reducing-agent ratio, we achieved precise control over crosslinking density (~13% to ~100%), enabling fine modulation of nanocarrier stability, encapsulation efficiency, and drug release kinetics. Notably, highly crosslinked nanonetworks exhibited exceptional robustness under physiological conditions and showed ~80% sustained release of the model chemotherapeutic drug doxorubicin (DOX) under simulated intracellular redox conditions of cancer cells. Furthermore, the dynamic covalent nature of the poly(disulfide)s facilitated controlled depolymerization and complete recyclability back to the monomeric state upon treatment with external thiols, demonstrating the reversible and sustainable nature of the system.

Biological evaluations revealed environment-specific surface charge modulation, driving cancer cell-selective uptake and cytotoxicity, while maintaining excellent biocompatibility with normal cells. The combination of ease of synthesis, reproducibility, robust stability, triggered drug release, and selective cytotoxicity underscores the potential of this biomass-derived nanonetwork platform as a next-generation chemotherapeutic delivery system.

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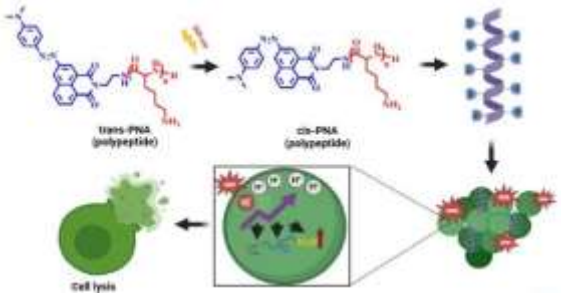
A Smart Polypeptide-Based Photoresponsive Nanotherapeutics Against Methicillin-Resistant Staphylococcus aureus

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Antibiotic resistance in bacterial pathogens, exemplified by methicillin-resistant Staphylococcus aureus (MRSA), represents a critical challenge in contemporary medicine due to associated high mortality rates and the ineffectiveness of conventional therapies for conditions such as sepsis and pneumonia.[1-3] In response to this urgent issue, we report the development of azobenzene-functionalized, photoresponsive polypeptide nanofibers (PNFs) designed to structurally and functionally mimic host-defense peptides. The synthetic approach utilizes ring- opening polymerization of N-carbobenzoxy-L-lysine N-carboxyanhydride (Cbz-L-Lys NCA), initiated by NAP-AZO, to incorporate azobenzene moieties directly into the polypeptide backbone. Spectroscopic and functional analyses demonstrate that light-induced conformational dynamics impart the PNFs with tunable membrane activity, enabling real-time modulation of their interactions with bacterial cells. The strategic inclusion of lysine-derived amino groups enhances electrostatic membrane disruption, while the azobenzene functionality facilitates photoactivated generation of reactive oxygen species (ROS), together mediating potent antibacterial effects against MRSA. Collectively, this study establishes that photoresponsive PNFs offer a dual-mode mechanism—membrane perturbation and ROS induction—for effective eradication of drug- resistant bacteria. The modular design and precisely controllable therapeutic action highlight these PNFs as promising candidates for future development of advanced antimicrobial materials.

Keywords: Methicillin-resistant Staphylococcus aureus (MRSA), Polypeptide nanofibers (PNF), ring-opening polymerization (ROP), reactive oxygen species (ROS), N6- carbobenzoxy-L-lysine (N6-Cbz-L-lysine), N-carboxyanhydride (NCA).



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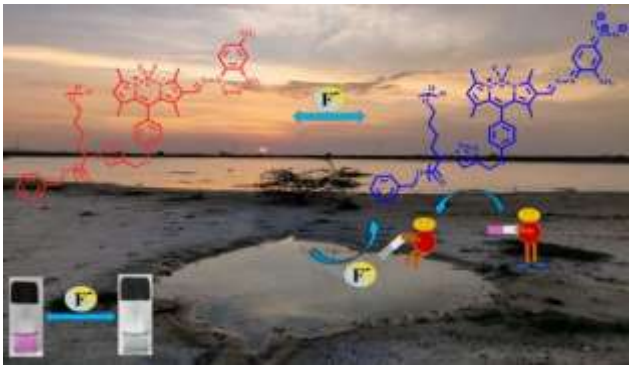
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Development of a Biodegradable BODIPY-ε-Caprolactone System for Rapid Colorimetric Detection of Fluoride Ions in Environmental Samples

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Fluoride ions (F^-) play vital roles in oral health and bone strengthening but can cause severe health issues such as dental fluorosis, urolithiasis, and even cancer when consumed in excess.[1-2] Therefore, accurate and rapid detection of fluoride is essential for environmental and biological monitoring.[3] In this study, we developed a highly sensitive and selective BODIPY-based aldehyde functionalized with 2,4-dinitrophenylhydrazine (BDNP) as a colorimetric and ratiometric sensor for F^- detection. Upon interaction with fluoride ions, BDNP exhibited a remarkable pink-to-grey color transition along with a distinct redshift in its absorbance maxima, enabling clear naked-eye detection. Furthermore, a biodegradable and biocompatible ε-caprolactone-based polymeric derivative (Poly-BDNP), synthesized via ring-opening polymerization (ROP), demonstrated even higher sensitivity and faster fluoride recognition compared to the monomer. UV–visible spectroscopic and ^{1}H NMR titration studies revealed that fluoride-induced deprotonation of N–H moieties triggers an intermolecular charge transfer (ICT) process responsible for the observable color change. The detection limits for BDNP and Poly-BDNP were determined to be 7.73 μM and 87.9 nM, respectively, showcasing the excellent analytical performance and real-world potential of this sensing system for fluoride monitoring.



Keywords: poly(ε-caprolactone), 2,4-DNP hydrazine, ROP, inorganic fluoride, colorimetric sensor.

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An Injectable Cyclodextrin-Extended Polyurethane/Carboxymethyl Cellulose Hydrogel for Controlled Release of Insulin: In-vitro and In-vivo Diabetic Animal Model Study

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Diabetes mellitus is a chronic metabolic disorder characterized by impaired insulin secretion or insulin resistance, leading to disrupted glucose homeostasis and elevated blood glucose levels[1]. Conventional management typically relies on frequent subcutaneous insulin injections to maintain normoglycemia; however, this approach often suffers from low patient compliance, localized insulin amyloidosis, and limited therapeutic duration. Several alternative routes of insulin administration, such as oral, inhalation, buccal, and transdermal delivery, have been extensively explored to overcome the limitations and patient discomfort associated with frequent subcutaneous insulin injection[2,3]. In our study, we have developed an injectable cyclodextrin-extended polyurethane/carboxymethyl cellulose (PU-co-CD/CMC) hydrogel for sustained insulin delivery[4]. The unique structural design of the PU-co-CD copolymer, combined with CMC, enables the formation of an injectable hydrogel matrix suitable for controlled drug release. The synthesis and structural properties of the copolymer are confirmed through spectroscopic, chromatographic, and rheological analyses. In vivo studies using diabetic Swiss albino mice demonstrated that subcutaneous administration of insulin-loaded PU-co-CD/CMC hydrogel achieved prolonged and steady insulin release for up to 72 hours, significantly outperforming conventional insulin injections (<12 hours). Histopathological evaluations confirmed the biocompatibility and biodegradability of the hydrogel, with no observed adverse effects on major organs. These findings suggest that the PU-co-CD/CMC hydrogel is a promising platform for sustained insulin delivery, offering an effective strategy for improved diabetes management. The gel depot formation in mice model and the in vivo insulin release profile are evaluated by monitoring blood glucose levels after subcutaneous administration of PU-co-CD hydrogel, PU-co-CD-insulin (PU-co-CD-INS) hydrogel, and pure soluble insulin. The PU-co-CD-INS hydrogel exhibited sustained insulin release with prolonged glucose regulation compared to the rapid decline observed with soluble insulin, as shown in Figure 1.

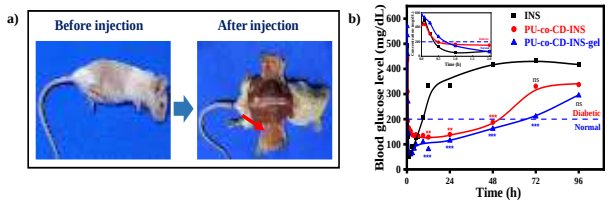


Figure 1: a) Gel depot formation study in mice model; b) In vivo release behavior of insulin from PU-co-CD and PU-co-CD-INS-gel as compared to pure soluble insulin applied through subcutaneous injection.

Keywords: diabetes; insulin delivery; chain extended copolymer; sustained release; injectable hydrogel.

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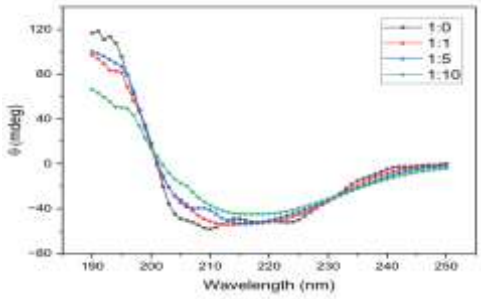
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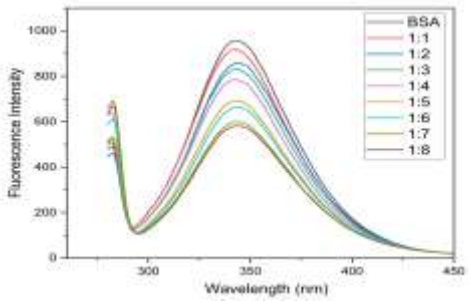
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A Comparative Study of Binding Interactions of Anticancer Drug, Gemcitabine with Serum Albumins using Multi-Spectroscopic and Computational Techniques

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Proteins, as natural bio-polymers of amino acid units, play a pivotal role in mediating essential biological processes and serve as key targets for therapeutic interventions. Understanding the binding mechanisms of protein–drug interactions is fundamental for rational drug design and improving pharmacological efficacy. In this comparative study, a comprehensive approach integrating multi-spectroscopic techniques with computational modelling was employed to probe the molecular recognition between serum albumins i.e. BSA, HSA, Lys and anticancer drug, Gemcitabine. UV–Vis absorption and fluorescence quenching analyses provided insights into binding affinity and conformational alterations, while circular dichroism (CD) spectroscopy revealed secondary structure perturbations upon complex formation. Additionally, molecular docking and molecular dynamics simulations were performed to validate experimental findings, elucidate binding sites, and characterize the stability of protein–drug complexes at the atomic level. The synergistic application of these techniques not only delineates the thermodynamic forces such as hydrogen bonding, hydrophobic interactions, and van der Waals forces that govern binding, but also highlights structural dynamics critical for biological activity. This integrated strategy underscores the potential of polymers like proteins as versatile biological platforms, bridging molecular biophysics with life-science applications, and offering new perspectives for drug discovery and targeted therapy.





Keywords: protein–drug interaction, natural polymers, spectroscopy, computational modelling, anti-cancer drug.

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Protein Delivery to the Cytosol and Nucleus via Micellar Nanocarrier-Based Nonendocytic Uptake

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Efficient delivery of biomolecules to the cell nucleus is critical for therapeutic success, yet conventional endocytic pathways are hindered by endosomal entrapment and enzymatic degradation. Here, we report a micellar nanocarrier system that achieves rapid, nonendocytic protein transport into the cytosol and subsequent nuclear localization. The carrier is based on phenylboronic acid-terminated polyaspartic acid micelles that form reversible covalent interactions with proteins through epigallocatechin gallate (EGCG) linkage. Guanidinium groups incorporated in the micelle facilitate direct membrane penetration by transient salt-bridge interactions with cell surface phosphates, enabling bypass of endosomal trafficking. Using this strategy, proteins of different molecular weights and charges were delivered efficiently into the cytosol within 15 minutes. Remarkably, low-molecular weight proteins such as lysozyme localized efficiently in the nucleus, while larger proteins (e.g., BSA, transferrin) remained cytosolic. Mechanistic investigations revealed that uptake occurs via an energy-independent, nonendocytic pathway, and nuclear trafficking is primarily governed by passive diffusion through nuclear pores. This platform demonstrates a versatile, modular approach for protein delivery, providing a promising strategy for nucleus-targeted therapeutics, intracellular drug delivery, and protein-based therapies.

Keywords: Polymer micelle, Nonendocytic uptake, Protein delivery, Nucleus targeting,

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Drug-eluting electrospun meshes to reprogram tumor-associated macrophages

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Despite significant progress in conventional treatment modalities for cancer, the suboptimal clinical outcomes of chemotherapy, hormonal therapy, etc., are attributed to challenges faced with short-lived effects, high frequency of administration, adverse side effects, and the development of resistance [1]. Though immunotherapy has gained wide acceptance in the clinical setup as targeted therapies for modulating the immune system, the effectiveness of this approach is limited due to extremely high manufacturing costs and the very short shelf life [2]. Hence, there is an urgent need to develop affordable clinical therapies to circumvent these limitations while ensuring long-term efficacy with minimal off-target systemic effects. To achieve this, we leverage the advantage of electrospinning techniques to develop a localized platform that co-delivers multiple drugs in a sustained manner within the therapeutic window, minimizing the need for repetitive administrations, thereby enhancing the potential for therapeutic efficacy. Specifically, we propose the development of a dual drug functionalized implant that can simultaneously deliver both drugs over extended time frames. The rationale for choosing the drug combination stems from the critical role of tumor-associated macrophages (TAM) in the tumor microenvironment (TME) and their implications on tumor survival, vasculature, and metastasis [3]. Accordingly, meshes were fabricated by modulating the fiber diameter and processing parameters while capitalizing on the advantages of polymer chemistry to achieve differential release rates over 4 weeks. The released drugs exhibited the ability to polarize TAM macrophages *in vitro* in a synergistic manner. These results suggest that the strategy pursued in this study can be leveraged for modulating TAM responses and could potentially serve as a platform to co-deliver multiple therapeutics in a localized manner with minimal off-target effects.

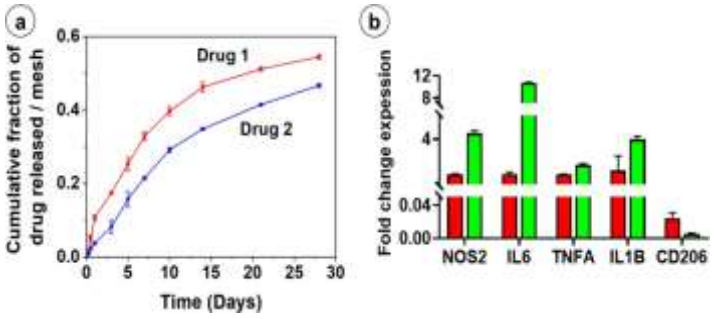


Figure 1: Implications of dual drug on macrophage polarization (a) Differential release of dual drug from electrospun mesh (b) Polarization effects of drugs on gene expression of RAW 264.7 cells.

Keywords: Tumor-associated macrophage, electrospun mesh, co-release.

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4.

Thermo-Responsive Europium Hydroxide Nanorod-Incorporated Nanofibrous Scaffolds for Antibacterial, and pH-Monitoring Wound Dressings in Diabetic Wound Healing

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Significant efforts have been devoted to the enhancement of wound dressings that encompass a diverse range of functionalities, including accelerated cellular proliferation, sustained drug release, protection against pathogenic infections, and the facilitation of wound condition monitoring, all aimed at expediting the healing of diabetic wounds while reducing the risk of secondary infections stemming from said wounds. Nonetheless, the accurate diagnosis of wound conditions remains a formidable challenge, as does the integration of the aforementioned functionalities without reliance on specialized apparatus and the necessary expertise in the domain of wound management. In this research, we synthesized and fabricated thermo-responsive nanofibers and infused Tetracycline hydrochloride alongside Europium hydroxide nanorods (EHNR) into the nanofibers to promote stimuli-responsive drug release and to exhibit antibacterial, antioxidant, and angiogenic properties. The scaffolds exhibited significant antimicrobial efficacy against both E. coli and S. aureus at optimized EHNR loading levels. The biocompatibility of these scaffolds was assessed utilizing the MTT assay as well as FDA-staining methodologies. A molecular understanding of the wound healing process was further corroborated through flow cytometry analysis and immunocytochemistry imaging studies, which revealed an increased population of collagen-I (COL-I)-/alpha-smooth muscle actin (α-SMA+) cells, thereby accelerating the closure of wounds. The in vivo experiments conducted on diabetic wounded murine models demonstrated that the developed scaffolds resulted in an impressive 95% reduction in wound size following a treatment duration of 21 days. Moreover, the ex vivo analysis illustrated that the developed scaffold could significantly expedite wound healing and promote skin tissue regeneration through the inhibition of inflammatory factors (TNF-α, IL-6) and the enhancement of angiogenesis via modulation of VEGF. The prepared nanofibrous patch was also capable of monitoring the pH of the wound microenvironment upon the incorporation of Phenol red into its matrix. In summary, this study underscores the potential of EHNR incorporated scaffolds as promising candidates for wound dressing applications that could be utilized in the treatment of diabetic wounds in future research initiatives.

Keywords: Electrospinning; Nanofibers; Thermo-responsive; Wound monitoring; Diabetic Wound Healing.

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Engineering Functionalized Hydroxyethyl Cellulose Based pH-Responsive Injectable Hydrogels Towards Drug Delivery and Bio-printing application

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Injectable hydrogels are promising drug carriers owing to their minimally invasive delivery, improved targeting efficiency and printable advanced biomaterial that facilitated a major role in tissue engineering. However, challenges related to their biodegradability and biocompatibility could hinder their effectiveness. Unlike conventional methods, it can print intricate 3D vascular networks essential for transporting oxygen, nutrients, and waste, bringing engineered tissues closer to mimicking natural ones. To address the dual challenges of creating biocompatible, biodegradable injectable hydrogels for drug delivery and printable materials for vascularized tissues engineering, a new hydrogel has been developed. The methacrylate hydroxyethyl cellulose (HEC-ma) and polyethylene glycol monomethacrylate (PEGMA, n=5) based hydrogel exhibits both shear-thinning behavior for injectability and the structural integrity that is needed for bioprinting. Olefin of (HEC-ma) and PEGMA were crosslinked with pentaerythritol tetrakis(3-mercaptopropionate) (PETMP) through free radical polymerization. This Thiol-ene "click" reaction executed the robust polymeric network[1]. The incorporation of HEC improves its biocompatibility, hemocompatibility, biodegradability. Due to its excellent injectability, the hydrogel can be delivered minimally invasively, which extends drug retention and improves localized treatment efficacy. Moreover, the inherent pH-responsiveness of the (HEC-ma)-PEGMA hydrogel enables controlled release of a model drug, Gentamicin sulfate (GMS), and Tetracycline Hydrochloride (TCH) at the target site.



Keywords: Cellulose, Injectable hydrogel, Drug delivery, Bioink.

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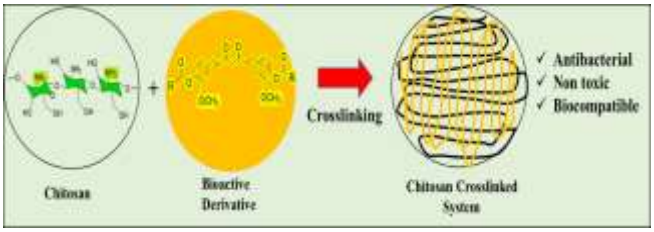
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Chitosan matrices crosslinked using bioactive derivatives

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This work focuses on addressing the need for novel, biocompatible materials with enhanced properties for biomedical applications. Chitosan is a well-known polysaccharide designed in bulk and nano form for various biomedical uses, such as oral and topical drug delivery systems. The developed chitosan materials are usually crosslinked using chemical agents like glutaraldehyde, succinic acid, and glutaric acid, which may not be fully compatible with biological systems due to their chemical nature. To improve the cell compatibility of chitosan, a novel bioactive cross-linker, a biomaterial derived from plant resources that is biodegradable, biocompatible, and environmentally friendly, was developed. Accordingly, curcumin, a bio-origin from plant resources, was derivatized and used to prepare cross-linked chitosan systems for biomedical applications. In our studies, we synthesized a bifunctional derivative as a crosslinker, characterized it (FTIR, NMR), and prepared crosslinked chitosan systems with various crosslinker concentrations. We evaluated the properties of these systems, such as mechanical and thermal properties. Additionally, cytotoxicity and antibacterial activity were assessed. The results demonstrated that crosslinking significantly improved the mechanical strength and thermal stability of chitosan. Cell viability studies showed that the system is cell-friendly and non-toxic. Antibacterial tests indicated that the system has antibacterial properties, suggesting it may have potential applications in biomedical fields.



Keywords: Bioactive crosslinker, curcumin derivative, biomedical materials.

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Radiofrequency actuated graphene oxide loaded polymeric particles for drug delivery applications

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Oral and intravenous methods are the conventional drug delivery routes which require repeated dosing to maintain the adequate level of drugs within the therapeutic window for a certain time limit. This causes either overdose of the drug, or lower the bioavailability of therapeutics, or premature drug absorption and excretion. Hence, extensive studies have been focused on the development of implantable drug delivery systems (IDDSs) which provide sustained delivery of therapeutics for prolonged periods by improving bioavailability.[1] Transdermal patches are one of the safest and highly recommended medical aids for topical drug delivery. A typical patch system consists of several layers where one of the layers (outermost) consists of a backing film, then an adhesive film which adheres to the skin and another layer is integrated with the biocompatible membrane consists of drug or reservoirs containing drug particles.[2] For our case, the aim is to develop a flexible wearable device primarily comprised of drug-loaded micro-particles made from Cellulose and Acetalated Dextran (Ac-DEX), co-loaded with graphene oxide nanoparticles (GOPs), where the micro particles will release the drug in a controlled manner for a longer period of time enhancing patience compliance. Ultimately, these microparticles will be incorporated into a polymeric reservoir/thin film, allowing for programmable, on-demand, site-specific drug release mediated by radio frequency (RF).[3] The crucial element for the drug release is graphene oxide (GO) which is a two-dimensional carbonaceous material with excellent thermal conductivity and can generate heat when exposed to RF fields. On the other hand, the biodegradable, hydrophilic polymer swells in presence of RF induced heating which further leads to pore formation through the cellulosic part and eventually accelerates the release of entrapped drug from the microspheres into the surrounding system through disintegration. Additionally, GO has a high surface area, biocompatibility (under a certain limit), and inherent surface functionalities, which facilitates better dispersion into the polymer matrix and improved drug loading.[4] The topical application of such system enhances the drug bioavailability which is administered to maximize the therapeutic effect via minimal sensitization of RF.[5] The RF-induced swelling triggers the controlled release of the encapsulated drug, while bursting out the swollen microspheres. This wearable technology is expected to provide significant therapeutic benefits for chronic wounds for long-term patient adherence.

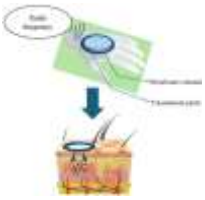


Figure 1. Drug release via the wearable patch containing drug loaded particles in presence of radiofrequency.

Keywords: biodegradable, triggered drug release, graphene oxide, radiofrequency, core@shell particles.

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Polymer–Microbiology Synergy: Sustainable Strategies to Attenuate Pathogenicity of Gram-Negative Bacteria

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The development of multidrug-resistant bacterial pathogens has been correlated with higher mortality, extended infection, and reduced effectiveness of existing antibiotics[1,2]. Conventional antibiotic therapy is often inadequate, leading to prolonged infections and high mortality. In the present study, we explored a polymer–microbiology interface to attenuate virulence traits rather than relying solely on bactericidal strategies. Synthetic biodegradable polymer was blended with natural biopolymer using either a neutral or acidic medium as solvent systems and subsequently stabilized with or without crosslinking. The resulting formulations were systematically evaluated for their effects on siderophore production and biofilm formation. Spectrophotometric measurements and CAS assays[3] demonstrated that acidic formulations had superior inhibitory activity against siderophore production compared to neutral-based medium. Crosslinked polymeric blends exhibited superior structural stability and stronger inhibition of virulence factors, likely due to denser network formation and enhanced interaction with bacterial cells. Consistent with these findings, biofilm assays also confirmed that polymeric treatments impaired biofilm development, with one of the polymeric blends contributing to more pronounced effects. In summary, our findings highlight the potential of biodegradable and biocompatible polymer blends as sustainable anti-virulence agents that target siderophore biosynthesis and biofilm maturation. This approach offers a promising strategy to reduce the pathogenicity of Gram negative bacteria while minimizing the selective pressures that drive antimicrobial resistance.

Keywords: Biofilm disruption; Siderophore inhibition; Virulence attenuation; CAS assay.

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Synthesis of Biocompatible Nanoarchitectures Using Amphiphilic Polythiourethanes for Dye Encapsulation

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Polythiourethane (PTU) chemistry has recently become a new frontier in polymer science based on dynamic covalent thiourethane linkages, structural robustness, and adjustable physicochemical properties. Historically, PTU polymers have been prepared by thiol–isocyanate chemistry, which allows for high degree of structural tunability and has been highly studied for functional polymer platforms. However, the dependence of harmful isocyanates results in severe environmental and safety issues, especially in the context of biomedical applications. This limitation has created an urgent need for alternative synthetic routes that retain the functionality of PTUs while enhancing environmental compatibility. In this work, we have adopted an alternative strategy based on the step-growth polymerization of dithiocarbonates and diamines.[1] It obviates the need for toxic isocyanates and provides a more environmentally friendly and safer pathway for functional PTU materials. At the same time, it exhibits the characteristic versatility of PTU chemistry, serving as molecular building blocks for the design of copolymers with adjustable amphiphilicity, as well as stimuli responsive properties. These properties make it very attractive for generating stimuli–responsive and biocompatible nanostructures that can be tunable for applications in nanomedicine. A particularly noteworthy feature of PTU systems is their inherent ability to undergo self-sorting, whereby distinct polymer domains spontaneously segregate to form multiple nanostructures. This phenomenon permits to produce different morphologies, such as vesicular aggregates (polymersomes) and spherical micelles, from the same polymeric precursor. The ability to achieve tunable morphology is valuable not only for studying the behaviour of the self-assembly with a range of π-acceptors, but also in practical applications in drug delivery and theragnostic, where different nanostructures can encapsulate and release therapeutic agents in a controlled manner.[2] In this study, we report the one-pot synthesis and self-assembly of polyethylene glycol (PEG)-based amphiphilic polythiourethanes (PTUs) bearing pendant aromatic ester groups.[3] All the polymers could form an aggregate with CACs in the range of 0.19-0.22 mg/mL with a hydrodynamic diameter of 40-98 nm with PDI 0.446-0.62. In addition, the aromatic ester in the PTU backbone as a pendant could stabilize and slow the exchange of encapsulated dyes better than the methyl ester containing polymer with a shorter spacer, as demonstrated by the FRET experiment. In addition, the developed method is versatile and can be modulated to tailor the properties of amphiphilic polymers; for example, degradation can be achieved by introducing a degradable motif in the diamine.

Keywords: Polythiourethane, Amphiphilic Polymer, Polymersomes, Micelle, FRET.

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Amine-based Sequence-Defined/ Conventional Polymers: Design, Synthesis, and Applications in Materials and Biological Sciences

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Developing macromolecules that are structurally and functionally tunable is still challenging, even though tunable macromolecules are essential for many applications. This motivated us to focus on engineering and developing macromolecules with tuneable functional groups over the polymeric chain for diverse applications. Sequence-defined polymer (SDP) is a unique macromolecule where the polymer has perfectly defined monomer sequences and chain length. Examples include peptides, protein and oligonucleotides. Control over the monomer sequence is the key to biological activities and it is inevitable for the essential features of life [1]. Amine-based macromolecule have gained attention recently due to diverse applications as pharmaceutical intermediates, drug/gene delivery agents, antibacterial drug, emulsifiers, cation exchange resins and catalysts. Motivated by the importance of polymeric amine compounds and sequence-defined polymer, an effort was made for the design and synthesis of a novel class of SDP by incorporating tertiary amines into the backbone from commercially available inexpensive materials. The strategy that was designed here is extremely efficient and economical for the scalable synthesis of the SDP via a support-free, protection–deprotection chemistry-free, and catalyst/template-free way. Most importantly, no extra design and synthesis of the monomer is required here [2]. After the synthesis, the biomedical applications, including the antibacterial activity of TA-SDO, were investigated against gram-positive (*B. subtilis*) and gram-negative bacteria (*E. coli*). The SDOs showed promising activity against these bacteria, and the activity of the molecules can be enhanced based on the sequences and side functional groups. These results underscore the significance of the sequences for practical applications. On the other hand, conventional polymers are simple to make, inexpensive, and less laborious. Similar to amine compounds, the dithiocarbamate (DTC) functional group possesses diverse applications in materials science and biomedical sciences. Inspired by the significance of tunable conventional polymers, DTC, and amine functional groups, we have developed a novel class of amine-DTC-based organic polymers. After synthesis and characterization, the polymers were utilised for sensing and removal of multiple harmful heavy metal contaminants, capturing radioactive iodine from water and vapor, and removal of dyes from contaminated water. In summary, an effort was undertaken to design and synthesize functionally tunable macromolecules and explore their numerous applications in the domains of materials and biomedical sciences.

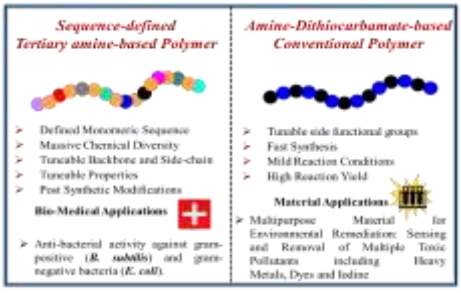


Figure 1. Graphical abstract of the Sequence-defined and Conventional polymer and their various applications .

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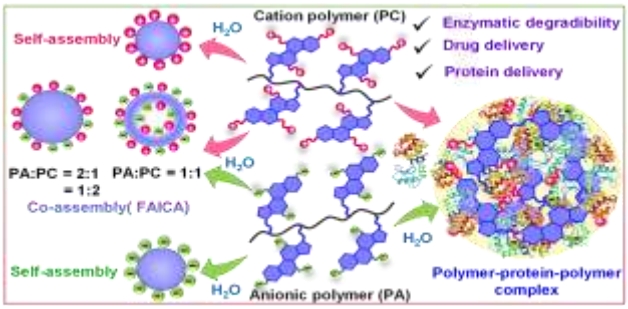
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Co-Assembly of Cholate-Conjugated Facially Amphiphilic Polymers and Their Enzyme-Responsiveness

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Inspired by the distinctive self-assembly behavior of bile acid–based facial amphiphiles (FAs), we developed a series of cholic acid–derived homopolymers and their coassembled nanoaggregates.[1] Individually, the cholate-pendant cationic polymer (PC; quaternary amine–based) and the anionic polymers PA1 (sulfate–based) and PA2 (phosphate–based) formed spherical nanoaggregates, governed by their intrinsic hydrophobic–hydrophilic balance. In contrast, coassembly of oppositely charged pairs (PC with PA1 or PA2) produced diverse nanostructures whose morphology was strongly dependent on mixing ratios.[2] Furthermore, we explored polymer–protein–polymer coassembly involving the oppositely charged FAs and therapeutic proteins of different charges (lysozyme and insulin). Characterization by UV–vis turbidimetry, TEM, and DLS revealed distinct aggregate architectures. Importantly, the ester, sulfate, and phosphate groups incorporated in PC, PA1, and PA2 imparted susceptibility to enzymatic degradation by esterase, sulfatase, and phosphatase, respectively. This enabled enzyme-triggered drug/protein release under physiological conditions.[3] Using this strategy, we successfully demonstrated controlled *in vitro* release of both small-molecule therapeutics (doxorubicin, DOX) and protein drugs (lysozyme, insulin) from the self-assembled and coassembled nanoaggregates. Overall, these findings highlight a versatile platform for engineering enzyme-responsive, bile acid–inspired nanocarriers with strong potential for next-generation therapeutic delivery.



Figures 1. Schematic illustration of self-assembly and co-assembly of polymers and their drug/protein delivery.

Keywords: Cholic acid, self-assembly, co-assembly, drug delivery, protein delivery.

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ESIPT Fluorescent Polypeptides to Study the Intracellular Organelle Fusion and Fission

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Polymer nanocarriers are emerging as an important integral of biomaterial science both in terms of delivery vehicles for therapeutic drugs and genes, as well as smart early diagnostic tools for detection of diseases in health care industry. Inter-organelle fusion involving endosomes and lysosomes as well as endo-lysosome-mediated lysosome fission are crucial processes that play a key role in regulating cellular homeostasis. Aberrations in either fusion or fission are implicated in many diseases. For instance, during malignant transformation, enhanced lysosome biogenesis increases the number, size, and activity of lysosomes. Furthermore, cargo uptake and degradation involving endosomes-lysosomes fusion are integral to the nanoparticle-assisted delivery of therapeutic drugs. Earlier efforts from our lab focused on probing the enzymatic-biodegradation aspects of fluorophore-tagged polymer nano-carriers and their co-localization at the lysosomal fusion for subsequent digestion to release the anticancer drugs by live cell bioimaging.[1-3] While understanding this intricate process can aid biodegradation aspects, tracking such events with minimal disturbance remains elusive due to the scarcity of single-component synthetic probes capable of distinctly and simultaneously labeling both endosomes and lysosomes. Past efforts have focused on developing genetic transfection-assisted Fluorescent protein-tag-specific probes. However, these techniques are limited by permeabilization steps, transfection efficiency, cell line dependency, expensive plasmid designs, unstable fluorescence after fixation, and reliance on two or more fluorescent dyes, among other challenges. Employing two dyes necessitates separate excitation sources, which can sometimes lead to spectral or excitation cross-talk, posing challenges when paired with similarly excitable fluorescent drugs or dyes during multiplex imaging. Recently, we have designed and developed an amphiphilic donor–π–acceptor-conjugated imine-based single-component micellar probe, Nano-emitter. The favorable orientation of the π-conjugated amphiphile in its micellar self-assembly stabilizes Excited State Intramolecular Proton Transfer (ESIPT) and fluoresces red at endosomal pH. Its hydrolysis to amine, PEG-Naph, at lysosomal pH, illuminates the lysosomes fluorescent green, with both forms excitable using a 405 nm confocal laser. The two-color labeling of endosomes and lysosomes enables the tracking of their fusion and lysosome-biogenesis processes using a single excitation laser. Its single wavelength excitation enabled its coupling with fluorescent anti-cancer drugs in multiplex time-lapse imaging, where we investigated the role of fusion and fission processes in lysosome-mediated doxorubicin sequestration in MCF-7 cells.[4] Our results showed that endosomes and endo-lysosomes also sequester doxorubicin, apart from previously recognized lysosomes. Currently, efforts are taken to maximize the ESIPT action in fluorescent probe functionalized poly(L-tyrosine) polypeptide nanoaggregates.[5] Bimolecular interaction between the polypeptide chains and the fluorescent cargoes were studied by FRET probe action in living cancer cells. Developing such systems advances the use of donor-acceptor architectures for bio-imaging applications. It strengthens the existing toolset for visualizing biological events. These versatile probes can enhance our understanding of drug sequestration and foster therapeutic strategies to mitigate cancer resistance.

Keywords: Fluorescent Probe, Polypeptides, ESIPT, Cellular biology, and Drug Delivery.

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Polyhydroxyurethanes based Smart Nanocarriers for dual-responsive Drug Delivery

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Stimuli-responsive polymeric nanocarriers have gained significant attention as "smart" drug delivery systems due to their ability to release therapeutics selectively within the tumor microenvironment, thereby minimizing off-target toxicity. In this work, we present phenylalanine-based Polyhydroxyurethanes (PHUs) as dual-responsive nanocarriers for targeted drug delivery. By variation of the incorporated diol from hydrophobic 1,10-decanediol (DD) to hydrophilic tetraethylene glycol (TEG), the amphiphilicity of the PHU backbone was tuned to form stable nanomicelles in aqueous solution. The additional π–π interactions and hydrophobicity imparted by the aromatic phenylalanine units enabled efficient encapsulation of doxorubicin (DOX), with higher loading efficiency, highlighting the advantage of the phenylalanine moieties. The drug-loaded nanomicelles exhibited remarkable stability in physiological settings (pH 7.4) while triggering a rapid drug release response in mildly acidic environments and in the presence of esterase, both of which are intrinsic properties of the tumor microenvironment. In vitro and cellular studies confirmed enhanced cytotoxicity of DOX-loaded nanomicelles against MDA-MB-231 breast cancer cells as compared to free DOX, highlighting their therapeutic potential. Overall, this study introduces phenylalanine-based PHUs as a green, biocompatible, and dual pH/enzyme-responsive platform for targeted cancer drug delivery.

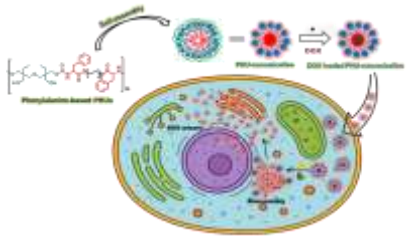


Figure 1. Schematic representation of formation and targeted drug delivery mechanism of DOX loaded phenylalanine-based PHU nanomicelles.

Keywords: Phenylalanine-based PHU nanomicelles, smart dual-responsive drug delivery, breast cancer therapy.

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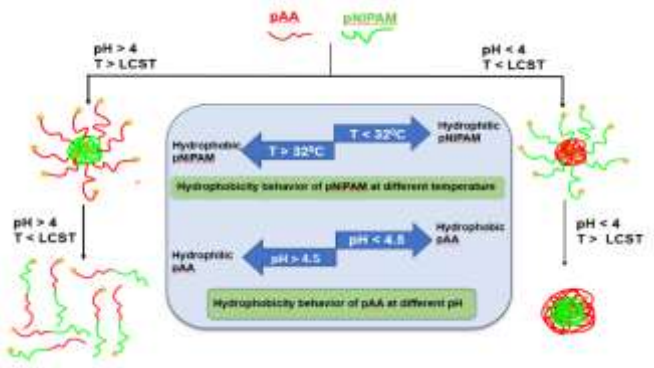
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Stimuli-Responsive Copolymer Micelles for Controlled Anticancer Drug Delivery

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Dual stimuli, e.g, pH and temperature-responsive polymers, are promising carriers for targeted drug delivery.[1,2] Here, random and block copolymers of poly (N-isopropylacrylamide-co-acrylic acid) [r(pNIPAM-co-pAA) and pNIPAM-b-pAA] were synthesized via RAFT polymerization with controlled molecular weight (10-50kDa) and narrow dispersities. NMR, FTIR, and GPC confirmed successful copolymerization and chain growth control, while TGA revealed distinct thermal profiles. DLS measurement showed that micelle size depended strongly on pH (3-6.5) and temperature (25-40 ^{0}C). Block copolymers assembled into smaller, more compact micelles, whereas random copolymers formed larger and less ordered aggregates. The successful encapsulation of doxorubicin hydrochloride (DOX.HCl) was confirmed by UV–Vis, fluorescence, and confocal microscopy. In vitro drug release experiments revealed that both copolymer types showed pronounced DOX release when exposed to acidic conditions (pH 4) and hyperthermia (40 °C). Block copolymer micelles showed a more pronounced stimulus-responsive behavior, whereas random copolymers demonstrated a gradual, diffusion-controlled release profile. These results imply that the pNIPAM/pAA copolymers can be strategically modified to control micelle stability and drug release profiles, providing a versatile platform for dual-responsive anticancer drug delivery applications.



Keywords*:* RAFT polymerization, dual-responsive polymers, Doxorubicin delivery, micelles.

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Star-Polymer Unimolecular Micelle Nanocarrier for Drug Delivery to Tumor Mice Xenograft

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The existing polymer nanocarriers in therapeutics are typically made via multi-molecular self-assembly into aggregated micellar nanoparticles. Unfortunately, these aggregated micellar nano-assemblies of both polymers and small molecules were known to disassemble under dilution factor of 100-1000 times (below their CMC) while administrating them for intravenous drug delivery under *in vivo* conditions. Therefore, a high concentration of injected drug formulation (above CMC) inevitably experience dilution under blood steam; thus, the impact of dilution factor on the aggregated nanoparticle stability under *in vivo* cannot be ignored. The recent accounts in biomaterials field have pointed out that less than 1 % of the nanocarriers based on polymers, small molecules or metal nanoparticle were found to exhibit promising output under the *in vivo* conditions. At this conjecture, one can foresee that the next generation polymer nano-scaffolds for *in vivo* drug administration are required to be designed to withstand against concentration gradient, and also if preferable in branched macromolecular architectures to make use of stability advantages. To accomplish this task, designing branched macromolecular architectures imbibed with single polymer chain or unimolecular micelle nanoparticle (UMNp) self-assembly is an elegant strategy. The unimolecular micelles, in principle, would be devoid of the destabilization against concentration gradient under *in vivo*. In this case, the increase (or decrease) in the polymer concentration would simply vary the number of carriers in solutions, as in the case of natural proteins in aqueous medium. This fundamental problem at chemistry-biology interface is addressed by us by carefully structure-engineering lysosomal-enzyme biodegradable star-polymer platform. For the first time, efforts have been taken to study the drug delivering capability both aggregated and unimolecular micelles were probed *in vitro* and *in vivo* mice xenograft (Pancreatic tumor) models.[1] Efforts are taken to study the role of arm-lengths and arm-numbers on the star polymers, linear versus block copolymers, etc in identifying appropriate geometry for unimolecular micelle self-assembly.[2-3] The star unimolecular micelle platform provided promising result in the anticancer drug delivery to solid tumor in mouse model had opened up avenues for testing several other drugs and disease models to enhance therapeutic efficacy.[4-5] Our efforts provide a systematic study on the advantages of biodegradable unimolecular micelles as the next generation nano-delivery platform that promises to circumvent the shortcomings of conventional multi-molecular micelles. The newly developed star-PCL polymers and their nano-assemblies are expected to make a significant contribution to long-term impact in the material and biomedical field.

Keywords: Star Polymers, Unimolecular Micelles, Polycaprolactones, Drug Delivery, Tumor Models.

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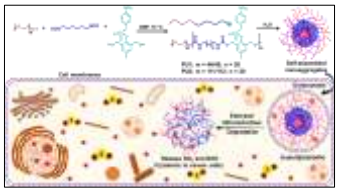
Nitroreductase (NTR)-responsive Degradable Theranostic Polymeric Sulfur Dioxide (SO_2) Prodrug for Hypoxic Cancer Therapeutics

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A novel polyurethane-based polyprodrug system, designed to release sulfur dioxide (SO_2) in response to nitroreductase (NTR), has been developed through condensation polymerization for enzyme-triggered gas therapy. The amphiphilic nature of these polyurethanes was characterized by determining their critical aggregation concentration (CAC), measuring hydrodynamic diameter (D_h), and conducting microscopic analysis. Enzyme-mediated degradation of the polyurethanes was verified using size exclusion chromatography (SEC), D_h measurements, and microscopic techniques. Furthermore, small molecular and polymeric fluorescent probes responsive to NTR and SO_2 were synthesized, with their responsiveness evaluated through 1H NMR and fluorescence spectroscopy. The system was further utilized to encapsulate the hypoxia-activated anticancer drug tirapazamine (TPZ) within the polymeric nanoaggregates. The release profile of TPZ was investigated under varying conditions, including two pH levels and in the presence of two enzymes (NTR and esterase). The highest TPZ release, reaching up to 63%, was observed at pH 6.0 in the presence of NTR, highlighting the system's responsiveness to specific enzymatic and pH conditions. The anticancer efficacy of the polyprodrug system, leveraging SO_2 as a cytotoxic agent, and the TPZ-loaded nanoaggregates, utilizing both SO_2 and TPZ as cytotoxic agents, was evaluated using cobalt chloride ($CoCl_2$) as a hypoxia-mimicking agent. These studies demonstrated significant anticancer activity, underscoring the therapeutic potential of the system. Cellular uptake and lysosomal trafficking of the polymers were tracked using epifluorescence microscopy, confirming effective internalization and intracellular distribution.[1,2] This work highlights the potential of NTR-responsive degradable polyprodrugs as a promising anticancer therapeutic platform. By integrating enzyme-triggered gas therapy with controlled drug release, the system offers a fresh perspective on targeted cancer treatment, combining the benefits of gas therapy and chemotherapy in a single, responsive polymeric framework.[3] The findings pave the way for further exploration of enzyme-responsive systems in precision medicine, particularly for hypoxia-associated cancers, with the potential to enhance therapeutic outcomes through tailored drug delivery and cytotoxic gas release.[4]



Figures 1. Schematic illustration of NTR-responsive polymeric SO_2-polyprodrug for anticancer therapeutics.

Keywords: Hypoxia, nitroreductase, gas therapy, sulfer dioxide, polymer, degradable, anticancer therapeutics.

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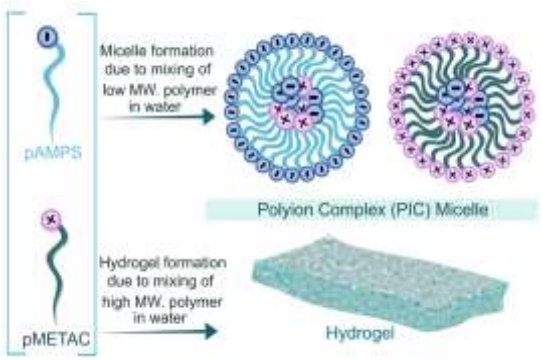
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Self-Directed Formation of Micelles and Hydrogels by Polyelectrolyte Coacervation

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Water-soluble homo copolymers, consisting of either anionic or cationic blocks, were synthesized via reversible addition-fragmentation chain transfer (RAFT) polymerization. The anionic polymer, poly(sodium 2-(acrylamido)-2-methylpropanesulfonate) (pAMPS), and the cationic polymer, poly(2-(methacryloyloxy)ethyl trimethylammonium chloride) (pMETAC), were prepared with controlled molecular weights (MWs) of 5 and 10 kDa, respectively. Molecular weights were confirmed by advanced polymeric chromatography (APC). When aqueous solutions of these oppositely charged copolymers were mixed, they spontaneously formed Polyion complex (PIC). At 5 kDa, the mixing resulted in the formation of PIC micelles, while the 10 kDa polymers formed instant hydrogels. The PIC micelles were characterized by ^{1}H NMR, dynamic light scattering (DLS), and scanning electron microscopy (SEM). The micelle's hydrodynamic size was dependent on the mixing ratio, reaching a maximum at the stoichiometric charge neutralization point. The hydrogels were characterized by swelling and rheological analyses. Both the PIC micelles and hydrogels demonstrated cytocompatibility. The PIC micelles were successfully used to encapsulate and deliver the hydrophobic drug indomethacin in vitro, while the hydrogels were effective carriers for the hydrophilic drug diclofenac sodium. This study highlights the potential of these polyelectrolyte complexes as versatile and biocompatible delivery systems for both hydrophobic and hydrophilic therapeutics.



Keywords: Raft-Polymerization, Physical mixing, Polyion complex micelle, Hydrogel, Drug delivery.

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Light-Driven Sol-Gel Phase Transition in an Ionic Hydrogel

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The precise control of light-responsive behavior in advanced materials is fundamentally dependent on the development of highly efficient, water-soluble azobenzene-based photoswitches. One of the key challenges in this domain is the design of photoswitchable systems that not only exhibit rapid and reversible photoisomerization under mild conditions but also integrate effectively into aqueous environments, particularly as crosslinkers in hydrogel networks. In this study, we report the rational design and synthesis of a novel water-soluble, cationic azobenzene derivative that functions as a multifunctional crosslinker for the fabrication of photoresponsive hydrogels based on the sodium salt of poly(2-acrylamido-2-methylpropane sulfonic acid) [Azo(+)@pSAMPS(-)]. The hydrogel architecture is stabilized through a combination of hydrogen bonding, electrostatic interactions, and π–π stacking, enabling a robust and responsive network. The photoisomerization behavior of the azobenzene units was systematically investigated using UV-Vis absorption and ^{1}H NMR spectroscopy, confirming efficient *trans*-to-*cis* conversion within seconds upon 365 nm UV irradiation. Structural and morphological characterization of the hydrogel was carried out via field-emission scanning electron microscopy (FESEM), rheological analysis, and UV-Vis spectroscopy, collectively demonstrating the material's responsive and reversible nature under light stimulus. Furthermore, the hydrogel matrix was successfully employed for the encapsulation of the chemotherapeutic agent doxorubicin hydrochloride (DOX), showcasing its potential as a light-triggered drug delivery system. Controlled drug release was achieved through external light irradiation, enabling precise spatial and temporal modulation of therapeutic delivery. Importantly, the azobenzene derivative was synthesized via a simplified, scalable, and cost-effective route, addressing major limitations associated with traditional azobenzene synthesis methods. Thus, this work presents a promising platform for the development of next-generation light-responsive hydrogels, with potential applications in targeted drug delivery, tissue engineering, and other biomedical fields requiring non-invasive external control.



Keywords: Azobenzene, Photo-triggered, Hydrogel, Rheology, Drug delivery.

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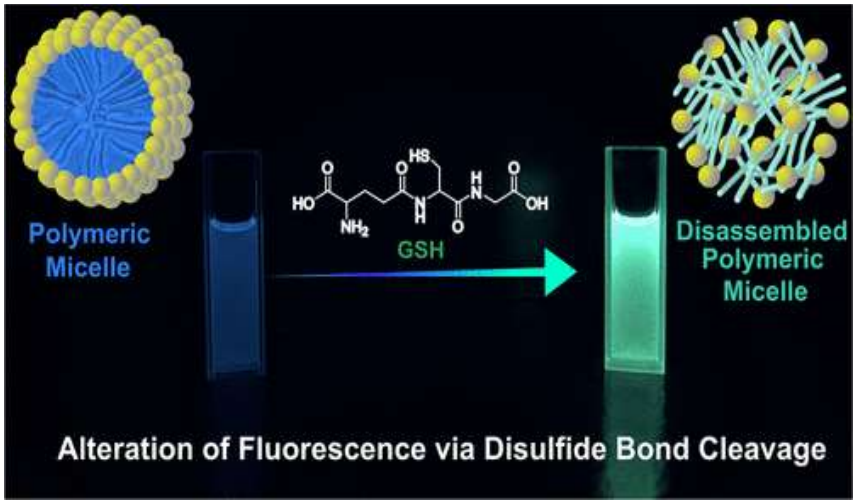
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Phthalimide-Derived Polymeric Micelles for Glutathione-Responsive Photoluminescent Sensing

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A theranostic drug delivery system was developed using a pPEGMA$_{22}$-*b*-pPTHDS$_{16}$ copolymer micelle. This system addresses a common challenge in drug delivery: the inability to accurately track a drug's release using just photoluminescence. The micelle is specially designed with a disulfide bond that serves as a cleavable linker, a phthalimide group for real-time fluorescence tracking, and curcumin as the therapeutic cargo. When the micelle encounters glutathione (GSH) inside the body, the disulfide bond breaks. This action simultaneously releases the curcumin and causes the phthalimide's fluorescence to shift to a longer wavelength, providing a clear visual signal that the drug has been successfully delivered. This dual functionality, which combines therapy with a diagnostic tool, demonstrates great promise for targeted therapies by allowing for the direct visualization of drug absorption at the cellular level.



Keywords: Glutathione-responsive, Polymeric micelles, Photoluminescence, Theranostic, Drug delivery.

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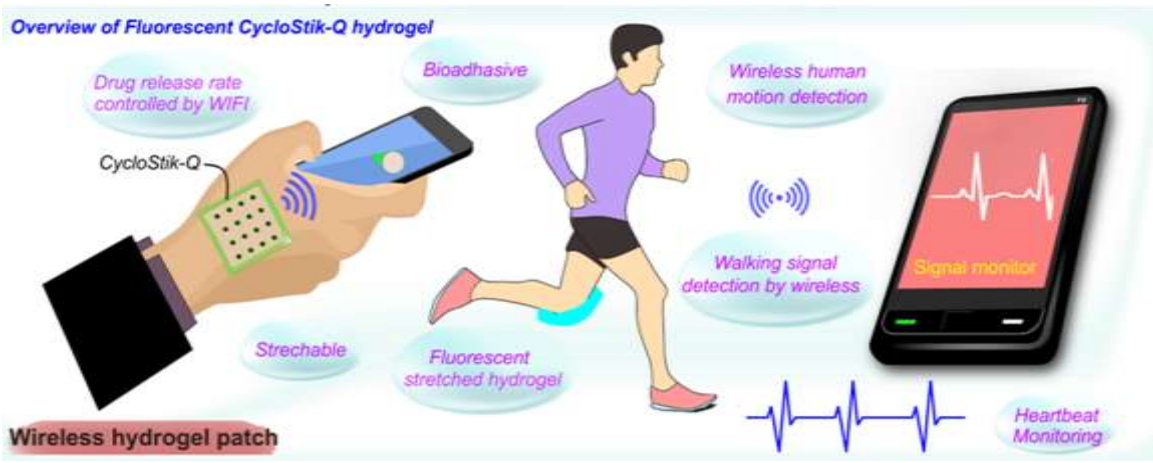
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Flexible Bioadhesive Nanocomposite Hydrogel for Wireless Electro-responsive Drug Delivery and Biomonitoring

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The integration of mechanically adaptive, conductive and bioadhesive hydrogels with wireless bioelectronics presents a promising path for human motion detection and health monitoring. However, combining strain sensing and electro-responsive drug release within one material remains difficult. To address this, we developed "CycloStik-Q," a nanocomposite hydrogel synthesized through free radical polymerization of β-cyclodextrin, N-hydroxymethyl acrylamide, and graphene quantum dots from cigarette smoke. This material exhibits a unique suite of properties: high stretchability, toughness, electro-responsiveness, pressure sensitivity, and antioxidant activity. We leveraged these traits to develop a single, wireless platform capable of real-time human motion tracking and precise, on-demand drug release, both controlled via Wi-Fi. This work demonstrates a significant step toward closed-loop, personalized therapeutic systems.



Keywords: Hydrogel, Electro-triggered, Wi-Fi enabled, Motion-sensor, Drug Delivery.

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Controlled-release nanoformulated herbicides for effective and long-term weed management

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Herbicides are widely used to control weeds competing with crops for water and nutrients, but only a small fraction reaches the target weeds, with much of it leaching into water bodies and causing environmental pollution. To address these challenges, nanoformulations have been developed to provide controlled release; however, synthetic polymer carriers often face biodegradability issues. In this study, we developed ethyl cellulose based nanoformulation as a biodegradable carrier for broadleaf-targeting herbicides (e.g., atrazine and diuron), aiming for slow and sustained release to ensure long-term weed control. Tomato plants were used as a model broadleaf weed to assess the efficacy of the formulations under pre-emergence, post-emergence, and re-emergence conditions. Morphological, physiological, and biochemical parameters were evaluated to determine herbicidal impact. Compared to conventional bulk formulations, the biopolymer-based nanoformulation demonstrated higher weed mortality at lower concentrations, alongside prolonged effectiveness, including suppression of weed re-emergence into the second crop cycle after a single application. These results highlight the potential of biopolymer-based nanocarriers as an eco-friendly and efficient alternative for sustainable weed management.

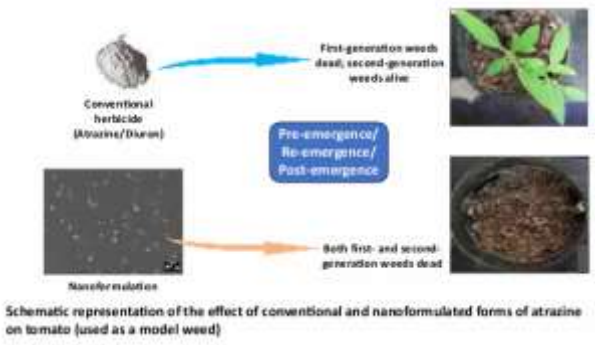


Figure 1. The effect of conventional and nanoformulated forms of atrazine on tomato (used as a model broad-leaf weed) in pre-emergence, re-emergence, and post-emergence experiments.

Keywords: Nanoformulation, weed mortality, herbicide, controlled release, oxidative stress.

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A Versatile Transesterification Methodology for Functional Degradable Polyesters from an Activated Diester Monomer and its Implication in Biomedical Applications

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Our work describes a facile condensation polymerization route to synthesize functional aliphatic polyesters through organo-catalyzed (4-dimethylaminopyridine) transesterification reaction[1] between an activated pentafluorophenyl-diester of adipic acid (A1) and various structurally different diols, ranging from simple linear and cyclic to quaternized naphthalene monoimide (NMI) moieties. The utility of this reactive ester chemistry enables us to obtain quantitative reaction conversion under mild conditions, prohibiting any backward reactions from the released pentafluorophenol with no requirement of by-product removal which has been a major drawback in the conventional polyester synthesis with non-activated diesters. Control over molecular weight was obtained by interplaying with the stoichiometric imbalance between the two monomers, which can be predicted from the infamous Carothers' Equation. Enzymatic degradation within 24 hours by random chain scission has been demonstrated, which can be tuned by playing with the hydrophobicity of the polyester backbone. Following this strategy, amphiphilic cationic polyesters with pendant NMI derivatives were prepared by pre-quaternization of the monomers with different aliphatic chain ends, viz. methyl and decyl chains, to design polyesters with positively charged hydrophobic pendant moieties.[2] These amphiphilic polyesters produced fluorescent nanoparticles in water exhibiting broad spectrum bacterial resistance against both gram-positive and gram-negative bacterium. Furthermore, systematic structure-activity relationship in such rarely reported dye-conjugated polyester backbones suggested the dual role of the aliphatic chain and the aromatic dyes in conferring biocidal activity against the bacterial cells with negligible toxicity towards mammalian cells. These polyesters also exhibited cellular uptake by endocytosis pathway and the presence of positively charged NMI-pendant head groups made the polymeric nanoparticles mitochondria specific after significant lysosomal escape.[3] Furthermore, the strategy was utilized in the synthesis of biotinylated polyesters for achieving cell selective uptake in cancer cells and exploration of their anti-cancer drug delivery property by virtue of the presence of a hydrophobic core appended from the attached fluorescent NMI which additionally enabled intracellular fluorescence tracking.[4] Thus, a versatile condensation polymerization methodology for devising functional degradable telechelic aliphatic polyesters has been established through the activated ester chemistry affording polyesters with quantitative conversion and wide variety of substrate scope, which could be implicated into the biological domain.

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Multi stimuli responsive polyester for cancer cell selective delivery and release of encapsulated cargo

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Polyesters, due to their tunable thermal, chemical and mechanical properties, find wide application in textile and packaging industry as well as in biological domain. In the recent past, research on stimuli responsive polymer has gained a significant attention, especially for biomedical applications.[1] Polyester, due to the presence of ester linkages in their backbone, can degrade in the presence of enzymes such as lipase or esterase which is already present in our body. This property makes polyester promising candidate for biological applications such as drug delivery. [2,3] In this study, we have synthesized two stimuli responsive polyesters, labelled as P1 and P2, using a facile methodology established in our lab.[4] P1 is a homopolyester with disulfide in the backbone and P2 is a random copolyester with disulfide backbone as well as biotin as a pendant. P2 is a water-dispersible copolyester which forms micellar like structure in water and is capable of encapsulating hydrophobic dye such as Nile Red. The presence of the disulfide in the backbone facilitates the degradation of the polyester selectively in cancer cells where concentration of GSH is much higher as compared to the normal cells. Stimuli responsive release of this dye is demonstrated, as a function of time as well as a function of concentration of GSH. Due to ester linkage, the backbone is also degradable in the presence of lipase. Degradation of the polyester in presence of both the stimuli, i.e GSH as well as Lipase, is further confirmed from DLS and Size Exclusion Chromatography. Additionally, it is also demonstrated in this study, that the polymer, due to the incorporation of biotin within it, can also exhibit selective uptake towards cancer cell and can deliver standard chemotherapeutic drug such as doxorubicin. In this presentation, I will discuss about the synthesis, characterization and stimuli responsiveness of these polyesters.

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pH-responsive Fluorescent-active Antifouling Microgels having Disulfide linkage for the Application of targeted REDOX-active Drug Delivery to the MDA-MB-231 Cancer cell

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This work reports the development of tailor-made functional microgels for the delivery of the anticancer drug doxorubicin (DOX) to cancer cells. Disulfide crosslinked microgels were synthesized through water in oil (w/o) mini-emulsion polymerization, followed by surface functionalization with rhodamine amine ($RhNH_2$, fluorescent active agent) and polysulfobetaine (zwitterion) brushes, respectively. Here, $RhNH_2$ responded to the microgel's pH variation by appearing in the emission range of fluorescence at 570-585 nm, and the occurrence of polysulfobetaine lessened model protein adsorption, which is here bovine serum albumin (BSA) (~18-20% reduction). This multi-responsive microgel was characterized using various methods. Synthesized microgels showed a % drug loading content (%DLC) of (7± 2)% as well as a % drug loading efficiency (%DLE) of 76 ± 5)%. Cytotoxicity of biopolymer-based microgel was characterized over MDA-MB-231 (IC_{50} 120-125 µg/mL) cancer cells through MTT assay, remarking that the designed microgel is non-toxic, although drug-loaded microgels exhibited consequential toxicity. To comprehend cell apoptosis along with the cancer cells' response to drug-loaded microgels, FACS, and cell uptake (*in vitro*) investigations were conducted. These fluorescent active, non-toxic, zwitterionic, and REDOX-responsive microgels could be a potential candidate for promoting a significant inhibitory effect on cancer cells.

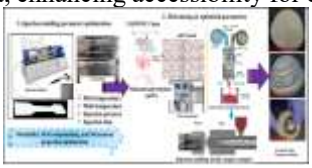
Key Words: pH-triggered fluorescent active, REDOX-active, zwitterionic, drug delivery, cancer cells.

Injection Molding Processing of UHMWPE Polymer for Orthopedic Implants

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The global orthopedic implant market is projected to reach USD 68.51 billion by 2027, driven by an aging demographic and increasing trauma cases. A critical challenge in this sector is that approximately 80% of these implants are imported and tailored for Western anatomies, complicating accessibility for economically disadvantaged patients in India. This research focuses on developing indigenous, cost-effective orthopedic implants, utilizing injection-molded medical-grade ultra-high molecular weight polyethylene (UHMWPE) to enhance moldability and performance. The selection of injection molding as a processing technique is motivated by its capacity to fabricate complex geometries with high dimensional accuracy while minimizing material waste, representing a novel application of this method for acetabular liners in the orthopedic domain. Traditional fabrication methods such as extrusion and machining are associated with elevated costs, significant material loss, and time-consuming. To augment the viscoelastic properties and flow characteristics of UHMWPE, we introduce an innovative polymer blend formulated with short-chain maleated polyethylene via melt compounding. Comprehensive characterization techniques, including FTIR, XRD, SEM, DSC, TGA, and mechanical testing of injection molded samples, demonstrated substantial enhancements in melt viscosity, with optimized injection molding parameters yielding tensile strengths exceeding 35 MPa. Overall, this research demonstrates improved injection moldability of UHMWPE by blending with maleated polyethylene via melt compounding while preserving clinical mechanical properties and successfully produced an injection molded acetabular liner components with no internal defect (3D micro CT) and dimensional accuracy for total hip arthroplasty applications that minimizing production waste. This research establishes a robust scientific and technical foundation for the mass production of "ready-to-implant" orthopedic bearings in India, enhancing accessibility for economically disadvantaged patients.



Figures 1 – Injection molding and melt compounding parameter optimization and AL prototype molding.

Keywords: Injection molding, UHMWPE, Orthopedic implants, Total hip and arthroplasty, melt compounding.

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Deciphering The Binding Interactions Of Anti-Cancer Drugs Using Multi-Spectroscopic Techniques And In-Silico Methods

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Proteins, the natural bio-polymer, play a vital role in maintenance and serve as the foundation for the body structure. They also serve as a vehicle for the transport enormous types of ligands, drugs, fatty acids etc. The binding interaction studies of two different classes of oncotherapeutic drugs, Alkylating agent and Anthracenedione, *viz*., Procarbazine (PCZ) and Pixantrone (PXN) respectively with Hen egg white Lysozyme (HEWL) was investigated employing multi-spectroscopic techniques and *in-silico* studies. Stern-Volmer analysis of fluorescence evidenced that both the anti-cancer drugs quench the intrinsic fluorescence spectra of lysozyme via static quenching mechanism. PCZ demonstrated comparatively stronger binding affinity towards lysozyme with binding constants, $K \sim 10^4$ and 10^3 for PCZ and PXN respectively at T = 298.15 K. The two drugs were found to led to increment in the polarity around Trp amino acid units as evidenced by synchronous and 3D spectral studies. Binding of the drugs resulted in significant alterations in secondary structure of lysozyme was confirmed by CD and FT-IR studies. Furthermore, computational studies provided the atomistic information related to binding of both the drugs and further validated the higher binding of PCZ over PXN. DFT and SIMULATION studies provided deep insights of binding of drugs in accordance with the experimental observations and results obtained.

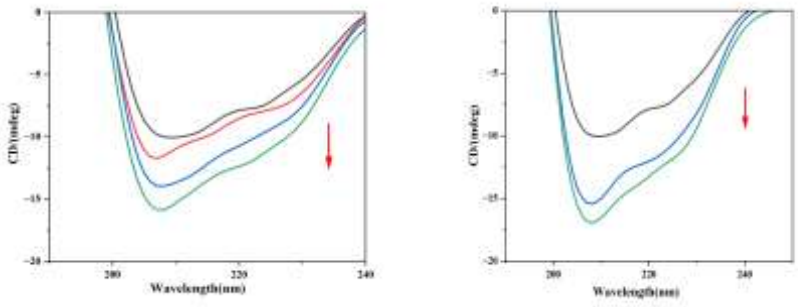


Fig.1*: Far-UV CD spectra of HEWL in in absence and presence of (a) PXN (b) PCZ at T =298.15 K and pH 7.4.*

Keywords: Procarbazine, Pixantrone, spectroscopic techniques, Stern-Volmer analysis.

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Cholic Acid-Based Tri-Armed Star Polymer Network: A Targeted and Sustained Drug Delivery System for Melanoma

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The growing challenge of therapy resistance in cancer treatment has created a significant barrier in clinical oncology, limiting the long-term effectiveness of conventional chemotherapy.[1] While agents like doxorubicin (Dox) can induce potent forms of tumor cell death, their standalone efficacy is often hindered by biological barriers and systemic toxicity. To address this, we report the development of a novel drug delivery platform composed of a polyurethane-based prepolymer (PP) and its cholic acid-modified derivatives lower graft CP1 and higher grafted CP2 , developed for sustained and targeted anticancer therapy.These formulations integrate structural flexibility and biodegradability, allowing them to adapt to dynamic physiological conditions, such as those encountered during injection or within irregular tumor micro-environments. The cholic acid modification imparts improved hydrophilic–hydrophobic balance , enabling enhanced interaction with Dox and controlled release kinetics. Among them, higher graft material CP2 demonstrates superior mechanical resilience, biocompatibility, and drug-loading efficiency, making it highly suitable for injectable therapeutic applications.In vitro cytotoxicity and intracellular trafficking studies in cancer cells, as well as biocompatibility assessments in normal fibroblasts, validate the therapeutic potential and safety profile of these systems. In vivo studies in melanoma-bearing mice demonstrate that CP2-based Dox loaded formulations, when delivered via a methylcellulose hydrogel just beneath the tumor site, offer superior tumor suppression while significantly reducing systemic toxicity. The injectable system sustains drug concentrations in the bloodstream for longer time period with respect to pristine Dox, attributed to the enhanced strain tolerance and structural durability of the formulation.Overall, this study presents a multifunctional drug delivery strategy using PP, CP1, and particularly CP2 based formulations, offering a promising avenue for cancer therapy through precise, prolonged, and biocompatible drug release bridging the gap between material innovation and therapeutic efficacy.

Keywords: Drug Delivery , Biocompatibility , Controlled release, Melanoma , Cancer.

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Tissue engineering with laccaic acid-doped polypyrrole nanofibrous mats

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Conductive polymers are bioactive scaffolds[1-2] for tissue regeneration because they send electrical signals to cells and tissues[3-4]. The hazardous chemicals used to dope conductive polymers may limit their biomedical use. Green polypyrrole synthesis used solid shellac laccaic acid. An electrospun nanofibrous mat of polyvinyl alcohol and glycolic acid (S3) received the nanostructured polymer. Scaffold biocompatibility and physico-chemical characterization were done. LAC@PPy nanofibers are antibacterial. Hemocompatibility studies showed S3 increased blood coagulation without harming red blood cells. SEM micrographs and phalloidin-DAPI staining demonstrated that the scaffolds were biocompatible with WI-38 and L929 cell lines, allowing rapid cell multiplication. The α-tubulin-positive cytoskeleton staining assay corroborated these results. Ultimately, the S3 matrix generates an artificial extracellular matrix that stimulates cell growth.

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Sustainable Fiber Development from Viscose Waste Using Ionic Liquid-Assisted Wet Spinning

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Conventional synthetic fibers, produced from petroleum-derived polymers through energy-intensive processes, generate persistent waste, microplastic pollution, and hazardous effluents that threaten ecosystems and human health. This growing environmental burden motivates the search for renewable, low-impact alternatives: viscose-waste based fibers derived from cellulose can reduce reliance on fossil resources and valorize agricultural residues, but traditional viscose processes use harsh, toxic reagents and produce problematic waste. Ionic liquids offer a promising, cleaner solvent option because they dissolve cellulose effectively, are nonvolatile, and can be recycled, thereby addressing both raw-material and solvent challenge. In this work, viscose waste was dissolved at different concentrations in ionic liquid and wet-spun into regenerated fibers; the dissolved samples were assessed for molecular weight to correlate polymer characteristics with performance. The produced fibers were tested for physical and morphological properties and expected to exhibit high tensile strength and excellent flexibility. By tailoring pulp concentration and spinning parameters, the process can be tuned for different end-use requirements such as apparel, technical textiles, or composites. This work therefore demonstrates viable route towards scalable, lower-waste cellulose fiber production that aligns with circular economy principles and reduces the environmental footprint of textile manufacturing. This approach enables easier integration with existing textile manufacturing workflows and could lower lifecycle environmental impacts when scaled with efficient ionic-liquid recovery.

Keywords: ionic liquid, viscose, regenerated fiber.

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Hierarchical Core–Shell Activated Charcoal-Reinforced PET Nanofibers Derived from Waste PET Bottles: Toward a Sustainable and Scalable Closed-Loop Carbon System for Formaldehyde Detection

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Formaldehyde (HCHO) and the disposal of polyethylene terephthalate (PET) represent critical environmental challenges. The synthesis of activated charcoal and the fabrication of electrospun PET nanofiber mats utilizing waste plastic bottles as carbon precursors demonstrate significant potential for formaldehyde detection. The application of solvent-based electrospinning facilitates the production of recycled PET nanofibers, incorporating varying degrees of activated charcoal loading (0−1.25 wt %). The material characteristics of these nanofiber mats were evaluated through a series of analytical techniques, including Scanning Electron Microscopy (SEM), Transmission Electron Spectroscopy (TEM), Infrared spectroscopy (IR), tensile testing, X-ray diffraction (XRD), Differential Scanning Calorimetry (DSC), and Water Contact Angle (WCA) assessment. The nanofiber film mat containing 0.75 wt% activated charcoal demonstrated the most favorable current response, which subsequently enabled its fabrication into a resistive sensor for HCHO detection via Electrochemical Impedance Spectroscopy (EIS). The developed sensor exhibited a broad dynamic response range (1−300 ppm), a low limit of detection (0.352 ppm), along with remarkable sensitivity, selectivity, and reproducibility. The electrospinning methodology employed to produce PET nanofiber mats, combined with the ionothermal synthesis of nitrogen-doped activated charcoal from recycled PET bottles, not only provides an efficient and highly sensitive platform for formaldehyde detection but also contributes to the establishment of a closed carbon loop. This flexible sensing platform possesses the potential to serve as an effective medium for the immobilization of various biological or hazardous chemical entities as recognition elements on the surface of the electrospun nanofibers, thereby facilitating the advancement of additional electrospun nanofibers aimed at creating ultrasensitive sensors with enhanced sensitivity and analytical efficacy. Furthermore, this sensor is applicable for detecting formaldehyde in contaminated milk samples, juices, and other liquid food products.

Keywords: Electrospinning,Circular economy,Nanofiber,Sensor.

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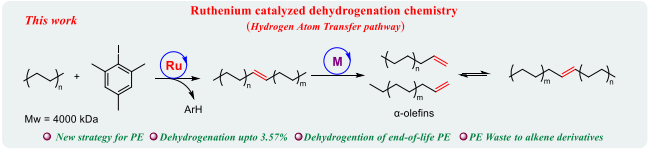
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Ruthenium-Catalyzed Upcycling of Waste Polyolefin to Value-Added Alkene

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Synthesis of value-added products from post-consumer waste polyolefins is fascinating as well as challenging. A decade later, Jia et al. embarked on advancing Goldman's catalytic transfer dehydrogenation method, leading to the discovery of cross-alkane metathesis of polyolefin chains. Their study harnessed an iridium pincer complex to generate double bonds within the PE chain, followed by a metathesis reaction employing $Re_2O_7/\gamma\text{-}Al_2O_3$ as catalysts to generate the oils and waxes.[1] Recently, Hartwig and group independently reported iridium POCOP catalyzed transfer dehydrogenation of PE followed by isomerization and ethenolysis. The selective synthesis of propene in 80 & 95 % yield respectively from waste polyethylene signifies the breakthrough in the degradation chemistry.[2] In addition to the cited reports, Coates et al. studies investigated the iridium-catalyzed dehydrogenation method in the absence of a sacrificial agent for synthesizing functional polyolefins.[3] Here we report ruthenium-catalyzed depolymerization of the polyethylene to long-chain alkene derivatives. The developed methodology mainly involves two steps i.e., dehydrogenation of polyethylene through hydrogen atom transfer and its metathesis using the HG-II catalyst. The dehydrogenation of polyethylene using ruthenium catalysis derived up to 3.57%, of double bonds; with 90% of the recovered polyolefin material. The obtained unsaturated polyethylene was subjected to cross-metathesis with ethylene using HG-II catalytic system. This resulted in the synthesis of predominantly dodecene (C12) derivatives, with 58% selectivity, along with other derivatives of varying chain lengths. The overall reaction produced terminal and internal olefins in the ratio 1:0.8, respectively. The dehydrogenation of polyethene and its deconstruction were confirmed from the NMR, Gel Permeation Chromatography (GPC) and Differential Scanning Calorimetry (DSC). The origin of C12 selectivity has been demonstrated by control experiments. The scope of the methodology was extended to post-consumer waste polyethylene, which gave high conversion of value-added dodecane derivatives as the major product.



Angew. Chem. Int. Ed. 2025, 64, e202422609
Keywords: • Degradation • Homogeneous catalysis • Ruthenium • Chemical Upcycling • Waste polyethylene • waste plastic

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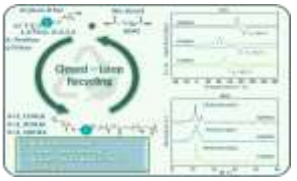
Closed loop recycling of biobased polycondensates: regulating properties with arylene ethers defects

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The macroscopic properties of polymers are primarily determined by their chain packing. Structural defects in these polymeric chains, such as branching, different chemical moiety or chemical irregularities in monomer-composition significantly influence the chemical microstructure of polymers. These defects can be either excluded or included into a polymer crystal packing, depending on their size and nature thereby resulting in change of polymeric properties. [1,2] And due to growing interest in the use of plant oils as feedstock to produce biobased polymers, research in this field of defects containing hydrocarbon has become increasingly important.[3] Also plastic production requires significant resources but plastics are largely discarded after use. Contaminants, and macromolecular structure degradation are all barriers to commodity polymer recycling. But by converting polymers back into monomers and purifying them before repolymerization, this problem can be easily handled. Materials recycled in this manner lose no characteristics, resulting in an ideal, circular polymer economy.[4]

This study presents a novel approach aimed at tuning the structure property relationship of arylene ether defects incorporated in the long bio-based aliphatic chain and to develop sustainable and closed-loop recyclable polymers. Specifically, it focuses on the integration of diol monomers containing arylene ether defects, 11,11'-(1,X-phenylenebis(oxy))bis(undecan-1-ol), (1,X -POU) where X=2,3 and 4, with renewable fatty acid-derived 1,16-dimethylhexadecanedioate (HDM), to produce polyesters bearing arylene ether defects. A series of polymers was prepared via melt transesterification of 1,X-POU with HDM by varying position of ether linkage, specifically ranging from ortho, meta to para position in polymer backbone. The properties of these polymers, which include crystallinity and melting temperature, were regulated. Finally, to achieve the closed-loop circular economy, the polymer was chemically degraded to its monomers. The recovered monomers were used to regenerate the polymer with near-identical material properties. This report presents a strategy to understand the defects in property tuning and the utilization of bio-derived feedstocks towards the development of a sustainable polymer. The design, synthesis and structural features of these copolymers will be discussed in detail in the presentation.



Keywords: biobased, defects, closed -loop recycling.

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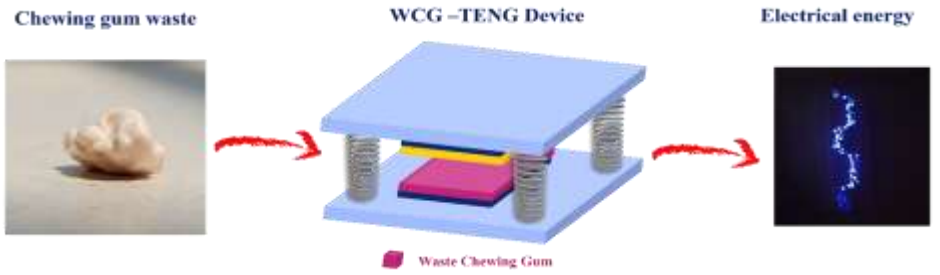
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Advanced Polymer Waste Upcycling: Transforming Discarded Chewing Gum into High-Performance Triboelectric Nanogenerators for Sustainable Electroplating Applications

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The growing problem of rubbery waste, especially from used chewing gum, not only harms the environment but also represents an untapped resource. Here, we show a new circular-economy solution that turns this common waste into powerful triboelectric nanogenerators (TENGs) capable of powering their own electroplating setups. By applying advanced surface treatments and adding nanocomposite materials, we greatly improved the flexible, energy-generating properties of the recovered gum. Our TENGs deliver exceptional performance—producing voltages above 60 V and peak power densities of 57 mW/m² when mechanically stimulated—far outperforming standard materials. They also remain reliable over more than 3000 cycles, retaining their flexibility and strength. The electricity these TENGs generate is enough to drive an entire copper-plating process without needing any external power source. This self-powered system points the way toward more sustainable manufacturing, eliminating the need for grid electricity in small-scale metal finishing.



Figures 1. Recycled Waste Chewing gum based Triboelectric Nanogenerator for Energy Harvesting.

Keywords: Recycling, Chewing gum waste, Triboelectric Nanogenerator (TENG), Electroplating.

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Cradle-to-Gate Boundary Definition for Pyrometallurgical Recycling of NMC811: A Life Cycle Assessment Approach

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The rapid deployment of Li-ion batteries (LIBs), particularly NMC8111 chemistries, has accelerated the need for efficient recycling pathways to mitigate critical metal depletion and environmental burdens. Pyrometallurgy, while industrially mature, remains underexplored in terms of life cycle inventory (LCI) boundary definition for environmental assessment. Here, we present a cradle-to-gate system boundary for the pyrometallurgical recycling of 1kg of spent NMC811 battery pack, integrating disassembly, smelting, alloy leaching, and hydrometallurgical refining. The inventory accounts for material recovery (0.190 kg NiSO4, 0.024 kg CoSO4, 0.040 kg Li2CO3) alongside process inputs (0.44 kWh electricity, 0.412 kg H2SO4, 0.305 kg H2O2) and direct emissions (0.709 kg CO2). This structured boundary bridges gaps in existing LCA studies, which often neglect slag, wastewater, and co-product flows, thereby underestimating impacts. The novelty lies in explicitly quantifying mass energy balances across pyrometallurgical sub-stages, allowing comparison with conventional and truncated hydrometallurgical routes. The developed framework provides a reproducible basis for future LCA of LIB recycling, enabling accurate assessment of carbon footprint, toxicity, and resource depletion under varying regional energy mixes. This work contributes toward harmonizing system definitions for recycling LCAs and advancing sustainable battery supply chains.

Keywords: Lithium-ion batteries, NMC811, Pyrometallurgy, Life Cycle Assessment, Recycling.

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Turning Plastic Waste into Protection: Ultrafine Nanofibers from Recycled Polyester for Eco-Friendly Face Masks

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Waste polyester bottles present serious environmental and societal concerns due to their non-biodegradable nature, contributing to both landfill overloading and microplastic pollution. Converting this persistent waste into value-added materials offers a sustainable pathway to mitigate such impacts. In this study, we report a facile approach for converting post-consumer polyester bottle waste into ultrafine nanofibres, achieving an average fibre diameter below 75 nm. These nanofibres were fabricated into nonwoven filter webs, both as neat polyester and as composites embedded with silver nano dots (AgNDs, ~3.5 ± 0.9 nm in size). The nanofibrous webs were integrated into a three-layer filtration structure by sandwiching them between two spunbonded nonwoven fabrics. This configuration significantly enhanced the particulate filtration efficiency from an initial ~10% to over 99%—while maintaining a low pressure drop (≤13 Pa at a face velocity of 5 cm/s), making the filters suitable for extended use in face masks. Moreover, the incorporation of silver quantum dots imparted effective antibacterial properties against both Gram-negative (Escherichia coli) and Gram-positive (Staphylococcus aureus) bacteria, further enhancing the personal protective function of the filters. Our findings demonstrate a sustainable and scalable method for upcycling PET bottle waste into high-performance, multifunctional filter media with potential applications in air filtration and personal protective equipment (PPE).

Keywords: recycling, ultrafine nanofibres, electrospinning, air filtration, antibacterial.

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Designing Heat-Resistant Self-Healable Adhesives through Polybenzoxazine Vitrimers with Dual Dynamic Networks

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High-performance adhesives are critical in aerospace, automotive, and electronics, where structural reliability under high temperatures is essential[1]. However, conventional thermoset adhesives suffer from irreversibility, limiting repair, recycling, and long-term sustainability. To address these challenges, we present a new class of polybenzoxazine-based vitrimers incorporating dual dynamic siloxane and imine linkages, engineered for self-healing and reprocessable adhesive applications[2]. Polybenzoxazine, known for their low flammability, thermal stability, and strong mechanical properties, serve as the backbone of this system. By integrating imine bonds, which allow rapid exchange and autonomous healing[3], with siloxane linkages[4], which contribute flexibility, toughness, and high-temperature endurance, we achieve a synergistic dual-network adhesive.

The resulting material demonstrated excellent thermal stability with adhesion performance maintained at elevated temperature and self-healing efficiency across multiple damage-repair cycles without significant loss of strength. Recyclability and reprocessability5, enabling circular use without compromising mechanical or thermal performance. This combination of repairability, recyclability, and durability under extreme conditions marks a significant departure from conventional thermoset adhesives. The dual-dynamic vitrimer design not only enhances functionality but also aligns with the growing demand for sustainable high-performance materials. Our findings establish a versatile platform for nextgeneration adhesives that merge structural strength with environmental responsibility. This innovation holds strong promise for industries requiring heat-resistant, long-life bonding solutions, offering pathways to reduce material waste and extend component lifetimes.



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Sustainable development of an eco-friendly vibration isolator by partial substitution of carbon black with ceramic wastes: Harnessing industrial wastes into the framework of the circular economy

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In the 21st Century, the pivotal concern of civilization is waste management. The generation vs utilization of different types of waste, considering the reduce, reuse, and recycle model, is where sustainability merges with the circular economy. The circular economy differs from the linear economy as it creates a perfect win-win for society, considering both waste management and the extended life cycle of products. Based on the growing concern of sustainability and waste management, this research article represents the development of an industrial waste-based antivibration mount using waste slag and silicon carbide (SiC) as a partial substitute for carbon black (CB) in a natural rubber matrix. The optimization involves the substitution of CB with slag and SiC. The dynamic isolation test was performed using a pre-designed vibration mount to establish a translational research model for the industry. Considering mechanical hysteresis, the composite containing equal loading of CB and slag demonstrated superior mechanical damping of 17% to the composite containing solely carbon black. The synergistic incorporation of slag and SiC provided a better balance of mechanical properties with dynamic recovery up to 96%. The vibration attenuation was predicted over a frequency range from 0.01 to 1000 Hz, which revealed that the combined effect of slag and SiC lowers the critical frequency from 150 to 117.5 Hz. Hence, this study shows the potential for 75% substitution of carbon black using waste slag and SiC, promoting a sustainable, eco-friendly composite, especially for vibration mitigation.

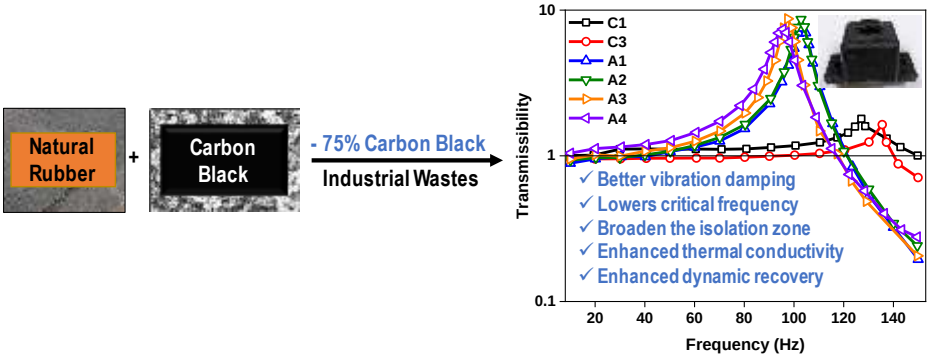


Figure 4: Graphical abstract

Keywords: Sustainability, Waste Slag, Silicon carbide, Vibration Isolation, Mechanical Hysteresis.

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Waste To Wealth: Upcycled Polyethylene Terephthalate Aerogels for Solar-Driven Atmospheric Water Harvesting

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Solar-driven atmospheric water harvesting (SAWH) offers a sustainable pathway to address global freshwater scarcity by coupling efficient water production with renewable energy utilization.[1] In this study, we present an innovative SAWH system that upcycles discarded polyethylene terephthalate (PET) bottles, one of the major sources of environmental pollution in soils and oceans, into a high-performance hybrid aerogel.[2] The aerogel is constructed from a porous PET framework integrated with polypyrrole (PPy) as a photothermal conversion agent, cellulose nanofiber (CNF) for mechanical reinforcement, and lithium chloride (LiCl) as a hygroscopic component. A PET/CNF/PPy thermoreversible gel is first prepared, followed by LiCl impregnation through solvent exchange and subsequent freeze-drying to yield a highly porous PET/CNF/PPy-LiCl aerogel.

The resulting hybrid aerogels feature hierarchical porous architectures that provide excellent cyclic stability, rapid regeneration, fast water uptake/release kinetics, and outstanding water vapor absorption capacity across a broad range of relative humidity (RH) and temperatures. Unlike conventional PET aerogels, which typically rely on toxic solvents or chemical crosslinking, this approach employs greener solvents and simultaneously valorizes PET waste, contributing to circular economy practices and environmental sustainability. The scalability and robust performance of this system underscore its potential as an eco-friendly and adaptable solution for freshwater production in diverse climatic conditions.

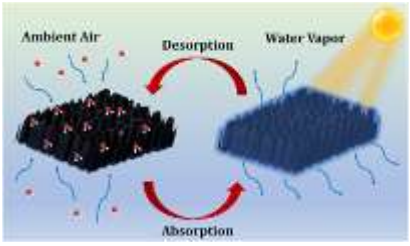


Figure: Schematic illustration of the water release process of PET/CNF/PPy-LiCl aerogel triggered by solar light irradiation.[3]

Keywords: Water harvesting, aerogel, PET, sustainability, thermoreversible.

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Depolymerization of Polyurethane Foam via Acidolysis Using Maleic Acid and Its Modification into Unsaturated Polyester Resin for Natural Fiber Composites

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Polyurethane (PU) foams contribute significantly to post-consumer plastic waste due to their crosslinked structure, which hinders conventional recycling. In this study, a sustainable approach is developed for chemical recycling of PU foam via Acidolysis using maleic acid as a depolymerizing agent. The process yields functionalized oligomers, which are subsequently utilized to synthesize unsaturated polyester resin (UPR). The resulting modified UPR exhibits double bond content, making it suitable for composite applications. This resin is reinforced with natural fibers, promoting a circular economy by integrating waste-derived matrix and bio-based reinforcement. Key mechanical properties such as tensile strength, flexural modulus, and thermal stability of the composites are evaluated and compared with commercial UPR-based composites to optimize formulation parameters and curing profiles. The study highlights process optimization and structure–property relationships to validate the reusability of depolymerized PU-based UPR. This work supports polymer waste valorisation and advances green composite technology through an integrated upcycling route.

Keywords: Polyurethane foam, Acidolysis, Maleic acid, Unsaturated polyester resin, Composite, Recycling, Process optimization.

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Radiation-Assisted Chemical Recycling of Polyurethane Foam Waste Using Itaconic Acid: Process Optimization and Machine Learning-Based Predictive Modeling

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Polyurethane (PU) foams, widely utilized across diverse industries, generate substantial post-consumer waste owing to their thermoset nature and inherent resistance to degradation, posing significant environmental challenges. This study presents a sustainable chemical recycling approach by employing itaconic acid, a bio-based cleavage agent, for the depolymerization of PU foam waste under solvent-assisted, catalyst-free conditions [1,2]. Process parameters including temperature, reaction time, and PU:acid ratio are systematically investigated to optimize the depolymerization conditions[3]. To enhance efficiency under milder operational settings, a gamma radiation-assisted pretreatment is introduced, significantly reducing reaction time and promoting effective polymer chain scission. Furthermore, machine learning models are developed to predict key product properties like acid value, hydroxyl value, and saponification value from the process parameters, enabling a comprehensive understanding of multivariate process-property relationships and facilitating data-driven process optimization [4]. The recovered polyols are evaluated for reusability in adhesive formulations cured with isocyanates, demonstrating performance at par with commercial adhesives[5]. This integrated strategy coupling green chemistry, radiation technology, and data science presents a promising pathway for circular recycling of thermoset polymers and contributes to sustainable management of polymer waste.

Keywords: Polyurethane, Machine learning, Acidolysis, PU adhesives, Depolymerization

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Dynamic Polyurethane Vitrimers: A Pathway to Recyclable and Self-Healing Polymer Systems

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Developing polymers that combine recyclability, mechanical resilience, and autonomous self-healing remains a major challenge in sustainable materials science.[1] Conventional thermosets, though mechanically strong, cannot be recycled due to their irreversible cross-linked structures, while thermoplastics lack sufficient durability for long-term use. Vitrimers, a new class of polymers with dynamic covalent networks, provide a solution by enabling reversible bond exchange, thus offering reprocessability along with strength and stability.[2,3] In this work, we report recyclable and self-healing polyurethane (PU) vitrimers synthesized through in-situ polymerization of hydroxypropyl methacrylate (HPMA) within a thermoplastic PU matrix, catalyzed by tin (II) 2-ethylhexanoate [Sn (Oct)$_2$]. The presence of hydroxyl groups from poly (hydroxypropyl methacrylate) (PHPMA) facilitates urethane–hydroxyl bond exchange, enabling efficient stress relaxation and recyclability without introducing new covalent linkages. Among the various formulations, PU-PHPMA-73-Sn(Oct)$_2$ exhibited the most balanced performance, combining tensile strength, flexibility, and recyclability. Remarkably, the material retained its functional properties after three recycling cycles, confirming its potential for closed-loop applications. Stress relaxation studies revealed composition-dependent bond exchange kinetics, with activation energies ranging from 21.6 ± 2.4 kJ/mol to 122.8 ± 8.1 kJ/mol, demonstrating the tunability of network dynamics. Thermal analysis confirmed good stability, while structural and morphological studies indicated strong interfacial bonding between PU and PHPMA phases. Most importantly, the vitrimer achieved up to 88.5% self-healing efficiency at 180 °C within 30 minutes, highlighting its ability to autonomously repair damage and extend service life. The integration of recyclability, mechanical resilience, and high self-healing efficiency positions these PU-based vitrimers as strong candidates for advanced applications in automotive parts, biomedical devices, adhesives, and sustainable coatings. This study establishes a scalable strategy to design next-generation polymers that address both performance and environmental sustainability.

Keywords: Vitrimers; Polyurethane; Dynamic covalent networks; Self-healing polymers; Recyclability; Sustainable materials.

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Dynamic Covalent Polyurethane Vitrimers from PET Waste and Castor Oil for Circular Material Design

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The rapid depletion of fossil resources and the environmental burden of plastic waste have created an urgent demand for polymers that are both bio-derived and recyclable. The dual challenge of designing bio-based polymers and valorizing plastic waste has intensified interest in polyurethane (PU) vitrimers and PET upcycling.[1,2] Polyurethanes (PUs), although versatile and widely used, are typically non-recyclable thermosets, while discarded polyethylene terephthalate (PET) bottles accumulate globally with limited options beyond downcycling.[3] Addressing these dual challenges, we developed a castor oil–based PU vitrimer incorporating bis(2-hydroxyethyl) terephthalate (BHET) derived from glycolyzed PET, merging renewable feedstocks with waste-derived building blocks. The optimized CO25 composition achieved a tensile strength of ~18 MPa, with robust polyurethane linkages enhancing mechanical durability and dynamic ester exchanges enabling reprocessability. Notably, mechanical properties were well-maintained across multiple recycling cycles, with strength increasing after the first reprocessing. The vitrimer also displayed excellent self-healing efficiency at 130 °C and strong adhesive performance, features absent in conventional PU. This study demonstrates a scalable strategy that addresses pressing environmental concerns by uniting PET upcycling and biobased vitrimer chemistry to create recyclable, self-healing, and high-performance materials.

Keywords: Vitrimer; Recycling; Upcycling; Dynamic Covalent Bond; PET waste; PU vitrimer.

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Reclamation of waste fish scales: A comparative assessment of water, acid and alkali treated fish scales for fibre reinforced composites

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Disposal of fish scale (FS), a waste protein is a challenging task especially in under developed countries. Reutilization of this abundant undervalued resource to manufacture green composites is a noble technique to maintain the ecology by reducing waste, carbon footprint and foster prosperity through innovative economic opportunities for fish sellers.[1] In this study, waste fish scales were subjected to three different surface treatments - water, acid and alkali; and their physicochemical properties were studied in order to optimize the most suitable method of treatment. Water treated FS showed least deterioration of properties. FS was converted to fish scale powder (FSP) and employed in making green composite by using it as reinforcing agent, Maleic Anhydride Modified Acrylated Epoxidized Soybean Oil (MAESO) as resin and Itaconic Acid-Glycidyl Methactrylate (IG) as diluent.[2] Vegetable oils are a valuable source of fatty acids with a high degree of unsaturation, which makes them a desirable initial raw material for the synthesis of bio-based resin. However, the unsaturated and ester linkages of vegetable oil aren't reactive enough for crosslinking purpose. Therefore, acrylic acid and maleic anhydride were added to epoxidized soybean oil in order to modify and increase their reactivity, making them useful as resin (MAESO).[3] The ratio of resin with diluent and FSP were kept as 55:45 while making the composite by compression molding technique. The resin and FS were characterized by various analytical techniques. Also the composites were assessed through measurement of mechanical properties, water uptake capacity, chemical resistance and impact strength. Water treated fish scale and its composite exhibited maximum improvement in overall properties.

Keywords: fish scale, epoxidized soybean oil, hydroxyapatite, sustainability, waste management.

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Advancing Sustainability with Vitrimer Chemistry in Biobased EPDM/ Recycled PP TPV

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The rising demand for sustainable polymeric materials requires the engineering of systems that exhibit enhanced durability and performance while maintaining processability and recyclability. Thermoplastic vulcanizates (TPVs) constitute a distinct category of soft-tough materials that merge the elasticity of rubber with the reprocessability of thermoplastics. However, Conventional EPDM/PP-based TPV, consisting of petroleum-derived EPDM rubber and virgin PP, utilizes a peroxide curing technique to crosslink the rubber phase, resulting in irreversible C–C bonds as crosslinks, which consequently restricts recyclability and sustainable material sourcing. This study introduces an innovative circular TPV system that integrates biobased ethylene propylene diene monomer (EPDM) rubber with recycled polypropylene (r-PP), which is subsequently cross-linked using vitrimer chemistry. The design of the TPV is based on associative covalent adaptable networks (CANs), particularly transesterification reactions. The β-hydroxy ester linkages are formed through interactions between the epoxy groups of epoxy-functionalized EPDM (e-EPDM) and the anhydride groups of maleic anhydride-grafted r-PP (MA-g-r-PP). These dynamic bonds can demonstrate exchange phenomena in the presence of a transesterification catalyst (zinc acetate), thereby addressing the limitations of traditional thermoplastic vulcanizates by facilitating self-healing and enhanced recyclability at elevated temperatures while preserving structural integrity during operational circumstances. The development of exchangeable β-hydroxy ester linkages as crosslinks has been confirmed from the unique torque-time behavior during the dynamic vulcanization process at Haake Rheomix and also evidenced by FTIR analysis. The TPV-vitrimer surpasses conventional peroxide-cured TPV and TPE in terms of crosslink density, tensile characteristics, and thermal-oxidative stability. Again, the recyclability tests indicated that the TPV-vitrimer maintained over 95% of its initial tensile strength after the first recycling cycle, whereas the peroxide-cured TPV retained 80%. Further, it has been revealed that after three recycling cycles, TPV-vitrimer maintains 84% of its tensile strength, comparable to peroxide-cured TPV following its first recycling. These results directly confirm the alignment of TPV-vitrimer with the real-world circularity in terms of long-term retention of the mechanical properties. From a sustainability standpoint, the manufacture of 1 kilogram of TPV-vitrimer decreases the carbon footprint by approximately 82% relative to conventional TPV composed entirely of petroleum-derived EPDM and virgin PP. In conclusion, integrating vitrimer chemistry into biobased EPDM/recycled PP blends yields a new class of circular TPVs with improved mechanical, thermal, and recycling performance. This strategy not only enhances TPV functionality but also offers a sustainable pathway for automotive, consumer, and industrial applications, highlighting the transformative role of vitrimers in advancing circular polymer systems.

Keywords: biobased EPDM, circular thermoplastic vulcanizate, vitrimer chemistry, sustainability, circular economy.

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Upcycled Plastic Waste- Carbon/MoS_2 as Electrodes for Supercapacitors- A Waste to Wealth Approach

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Plastic waste, which is regarded as a long-term hazard, can be upcycled to a high-capacity electrode material for supercapacitors[1]. Upcycling of plastic wastes to pyrolytic carbon for manufacturing energy storage devices could help mitigate their exponential accumulation and thereby reduce environmental issues[2]. Here, in this work, we have selected PET waste bottles (pw) for making activated carbon (pw-AC) because of their lasting nature, which takes 500 years to decompose naturally. The aC-based supercapacitors are widely explored and have limited capacitance and energy density as the major storage is by the electrical double layer mechanism, whereas combining aC with pseudocapacitive materials like MoS_2 could overcome these limitations by storing charge via a chemical process[3] which enhances the capacitance. In this study, we have synthesized a novel pwAC-MoS_2 nanoflower composite through a one-pot hydrothermal method. The composite exhibited an enhanced capacitance of 445 F g^{-1} at 0.5 A g^{-1}, which is comparatively higher than its physical mixture analog (pwAC-MoS_2 P) and literature reports of aC/MoS_2 composites. The faster charge transfer in the pwAC-MoS_2 due to enhanced pseudocapacitance was confirmed by the trasatti method.

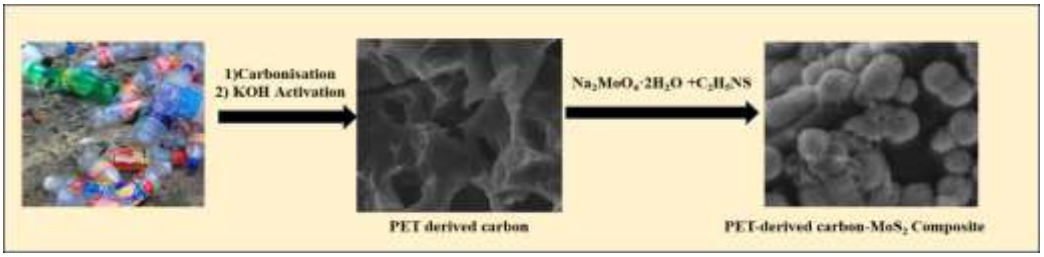


Figure 1. The schematic of the synthesis of the PET-derived carbon-MoS_2 composite

Keywords: Polyethylene Terephthalate, Molybdenum disulfide, Hydrothermal, Supercapacitors.

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Developing Agricultural Waste-Derived Adsorbent for Microplastics Removal

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Microplastics (MPs), plastic particles smaller than 5 mm in diameter, are now recognized as persistent pollutants in aquatic and terrestrial environments, posing growing threats to ecosystems and human health. Conventional removal methods such as mechanical filtration, chemical method, biological methods, and membrane technology for addressing microplastic pollution exhibit several significant limitations including generation of secondary wastes or use of toxic chemicals which further complicate environmental management.

This study investigates the development of sustainable adsorbents derived from agricultural wastes- such as bamboo, HEMP fiber, drumsticks, and others which may be suitably converted into activated biochar. As a rapidly renewing resource it may help mitigate the health risks and align with broader UNSEG environmental goals. Chemical activation using $FeCl_3$, KOH, and HNO_3 was employed to enhance porosity and surface area, well confirmed through XRD, FTIR, and BET analyses. CHNS (O) elemental analysis was conducted to determine the carbon, hydrogen, nitrogen, sulphur, and oxygen content, offering insights into the chemical composition and adsorption potential of the biochar through proximate and ultimate analysis.

Modified biochars were further doped with selected elemental ions to enhance interaction with MPs. Adsorption studies were performed using common microplastic polymers such as PET, PS, and polyolefins. Zeta potential analysis was used to assess surface charge and interaction dynamics. The study highlights the effectiveness of optimised biochar is contributing to sustainable and environmentally aligned approach for mitigating aquatic pollution.

Keywords: Microplastics (MPs), Functionalisation, Activated charcoal, Sustainable, Adsorption.

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Fabrication of biodegradable, mechanically strong, and flame-retardant dialdehyde cellulose-based oven-dried foams for packaging applications

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To address the current issue of plastic pollution, the fabrication of biodegradable and sustainable aerogels from agricultural waste presents a viable startergy. Cellulose, which is the most abundant polymer on Earth, shows inherent sustainability and biodegradability, which makes it suitable for various applications aimed at replacing plastic-based non-biodegradable materials. The upcycling of cellulose from agricultural waste not only addresses the issue of waste accumulation and stubble burning but also reduces the dependency on fossil fuels [1–3]. In this study, we have used rice straw as waste agricultural biomass to extract cellulose and then modify that cellulose to dialdehyde cellulose (DAC) using sodium metaperiodate to produce DAC-based foams through the ambient drying method. The process for the extraction of cellulose starts with the delignification of rice straw, followed by NaOH-based pulping to break the fibres. The pulp was then subjected to dialdehyde modification using sodium metaperiodate. By varying the concentration of sodium metaperiodate, DACs of different charge content (35 to 3000 µmol/g) were synthesised. The modified cellulose was cast and dried in the shape of circular foams through ambient drying (below 50 °C). Characterisation of fabricated foams was conducted using Fourier-transform infrared spectroscopy (FTIR), which concludes a hemiacetal peak at 880 cm-1 and cellulose backbone peak at 1100 cm-1, which shows inter- and intra-chain crosslinking due to the presence of aldehyde groups [4]. XPS analysis shows a high intensity peak for C=O, which is very low in delignified cellulose, confirming the presence of aldehyde groups. X-ray diffraction (XRD) analysis shows a reduction in per cent crystallinity in modified cellulose compared to unmodified cellulose (from 47.9% to 38.1%) due to oxidation and degradation of the cellulose backbone [5]. Scanning electron microscopy (SEM) of DAC foams shows a reduction of pore size (from 14.2 µm to 5.9 µm) and the formation of sheets with fibre degradation with the increase of charge content. Thermogravimetric analysis (TGA) and flame retardance tests conclude the char formation ability of DAC foams, suggesting flame retardance, flame stability and reduced thermal conductivity. Thermal imaging of DAC foam-based packaging shows superior performance as compared to conventional plastic-based packaging boxes. Furthermore, Life cycle assessment (LCA) studies indicate minimal environmental impact towards climate change and carbon footprint for our foam-based packaging. Our work suggests a sustainable, scalable, biodegradable, low-carbon footprint and circular economy-based approach for one-step modification and fabrication of DAC-based high-performance packaging material from waste agricultural biomass.



Figures 1. A. graphical representation of dialdehyde cellulose production from rice straw. B.possible crosslinking mechanism and different bonds between anhydro glucose units, C showing load-bearing capacity of the fabricated foam with a load of 900 g.

Keywords: Biodegradable, Sustainable, DAC, Foams.

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Development Of Water- And Oil-Resistant Barrier Coating From Waste Cooking Oil For Food Packaging Applications

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The excessive generation and mishandling of Waste Cooking Oil (WCO) mandates the need for its conversion into specialty resins and polymers for various applications1. This work focuses on the development of a bio coating from WCO for paper based packaging with improved hydrophobicity and moisture barrier properties. WCO was epoxidized and acrylated to form AWCO and subsequently characterized and modified into a water based emulsion using polyvinyl alcohol solution2. Aminopropyl triethoxy silane (APTES) was grafted in varying proportions to this emulsion, to enable crosslinking onto hydroxyl groups of cellulosic paper. The curing process of the coated paper (~ 40 gsm coating) was carried out at 130 °C for 5-7 mins to ensure complete crosslinking. The coated papers exhibited kit rating of 12/12, water contact angle of greater than 90°, along with excellent water retention, oil and ice repellency. Water vapor transmission rate (WVTR) got reduced to ~129 g/m2.day depicting the moisture barrier as well. High glass transition temperature (Tg) and thermal stability of the coatings revealed that they are fit for hot food packaging. The coatings most importantly depicted high repulping potential and home compostability, making it a commercially feasible replacement for the existing plastic liners in paper packaging.



Figure: Synthesis and properties of biocoating from Waste Cooking Oil.

Keywords: Waste Cooking Oil (WCO); Biocoating; Packaging; Hydrophobicity; Repulping.

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Selective Depolymerization of Poly(ethylene terephthalate) in Mixed Plastic Waste Using Magnetically Recoverable nZVI Catalyst

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The exponential growth in plastic consumption has escalated the global PET waste crisis, with current recycling methods falling short of achieving true circularity. Conventional mechanical recycling often results in material downcycling, producing inferior products unsuitable for high-value applications.[1] Chemical recycling, particularly depolymerization, offers a promising route to recover monomers for the regeneration of virgin-quality polymers. However, existing catalytic methods frequently suffer from limitations such as harsh reaction conditions, high catalyst toxicity, poor selectivity, complex separation steps, and limited recyclability, hindering large-scale adoption. While glycolysis offers a promising route to recover bis(2-hydroxyethyl) terephthalate (BHET) for virgin PET production, its industrial adoption is limited by slow reaction rates, high catalyst toxicity, and complex product purification.[2]
In this work,[3] we report an efficient and sustainable PET depolymerization process using magnetically recoverable nano zero-valent iron (nZVI) as a catalyst under optimized glycolysis conditions (1 wt% catalyst, PET:EG = 1:36, 180 °C, 4 h) (Figure 1). The system achieved complete PET conversion with >90% BHET yield, while the catalyst was easily recovered via magnetic separation and reused over multiple cycles without significant activity loss. The process exhibited high selectivity in mixed-plastic systems, depolymerizing PET while leaving BPA-PC largely intact. Additionally, ethylene glycol was recovered and reused, further enhancing process sustainability. This study demonstrates a green, scalable, and economically viable route for PET chemical recycling, advancing the development of closed-loop plastic management strategies.



Figures 1. Schematic representation of easy catalyst synthesis and the depolymerization process of commercial PET plastic.

Keywords: Selective depolymerization, PET, Plastic recycling, Waste management, Green chemistry.

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Upcycling acrylonitrile-butadiene-styrene into vitrimers by reactive extrusion with a commercial polyepoxide crosslinker

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With an increase in plastic production in the previous decade, the management of plastic waste has become an increasingly important topic for researchers to deal with. Plastic recycling, although a very prominent option has its drawbacks. Mechanical recycling, a preferred method for plastic recycling has limitations of poor mechanical integrity of recycled plastic compared to virgin plastic, which limits the applications of this recycled plastic [1]. Closed-loop recycling, which refers to the use of recycled plastic for the same application as that of virgin plastic demands that the mechanical integrity of the plastic should not be compromised during recycling [2]. To achieve this, scientists have increasingly turned to dynamic covalent bonds (DCB's) as a potential solution. Incorporating DCB's into thermoplastics to convert them into vitrimers improves the mechanical integrity of the plastics and preserves them during recycling which can enable the closed-loop recycling of various commercial thermoplastics [3]. In this study, we converted acrylonitrile-butadiene-styrene (ABS) into vitrimers via reactive extrusion which is a scalable and eco-friendly method widely employed in the polymer industry. The vitrimerization was carried out by crosslinking ABS with a commercial polyepoxide resin 4,4′ methylenebis-(N,N-diglycidylaniline) (TGDDM). The ABS vitrimers showed significant improvement in ultimate tensile strength (approximately 44%) and high retention of mechanical properties after three reprocessing runs. This strategy can potentially facilitate the closed-loop recycling of ABS and pave the way for a circular economy.

Keywords: acrylonitrile-butadiene-styrene, vitrimers, closed-loop recycling, upcycling, transesterification.

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Vitrimer-Enabled Circularity: Upcycling Mixed Polyolefin Waste from Milk Packets into High-Value 3D Printing Feedstock

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The global plastic waste crisis is exacerbated by the formidable challenge of upcycling mixed polymer streams, particularly the incompatible polyolefin phases of polyethylene (PE) and polypropylene (PP). Herein, we present a transformative strategy to address this issue by engineering a dynamic covalent vitrimeric system from post-consumer recycled polypropylene (PCR PP). By crosslinking maleated PCR-PP with a tetrafunctional epoxy, we fabricated a recyclable thermoset, or vitrimer, capable of fundamentally altering the material properties of mixed plastic waste. Our results demonstrate that this vitrimeric network significantly improves the interfacial compatibility between otherwise immiscible PCR PP and post-consumer polyethylene from milk packets (PCR PE). Characterization through rheology, gel content analysis, and SEM confirms the formation of a robust covalent adaptable network, which confers superior mechanical properties, including optimal tensile strength and enhanced dimensional stability under creep deformation. Critically, these vitrimeric blends retain their morphological and mechanical integrity across three reprocessing cycles, affirming their potential for genuine circularity. Furthermore, we successfully demonstrate the application of this upcycled material for additive manufacturing via Fused Granulate Fabrication (FGF), positioning a traditionally low-value waste stream as a high-value feedstock for 3D printing. The underlying molecular mechanism of this compatibilization is elucidated by DFT simulations, which substantiate the radical grafting and PE scavenging pathways, providing a theoretical foundation for our empirical observations. This work introduces a powerful and versatile platform for valorizing complex polyolefin waste, offering a scalable solution for transforming waste into functional and endlessly recyclable resources.

Keywords: Vitrimer, recycled polypropylene, polyethylene blends, transesterification, dynamic covalent network.

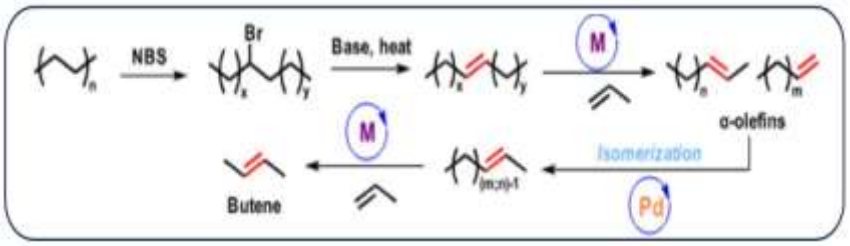
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Metal-Free Dehydrogenation-Upcycling Cascade for the Selective Conversion of Waste Polyethylene to Butene and Light Olefins

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Synthesis of a selective product from waste polyethylene (PE) is fascinating but an uphill task because of the intrinsic stability and chemical inertness of C-C & C-H bonds. Here we developed a methodology, consisting of two steps i.e., dehydrogenation of polyethylene through a metal-free approach and its isomerizing metathesis using the HG-II catalyst to produce 2-butene as a selective product, along with low molecular weight degraded olefins. The dehydrogenated polyethylene (DHP) was obtained through bromination of PE using NBS (N-bromo succinimide) and AIBN (Azobisisobutyronitrile), which gives 12% brominated polyethylene (BrPE), followed by dehydrobromination yielding DHP with 2.0 % unsaturation. The obtained unsaturated polyethylene (DHP) was further subjected to isomerizing cross-metathesis using an HG-II catalytic system. This resulted in the synthesis of predominantly butene gas (C4), as confirmed by NMR and GC-MS. The overall conversion was found to be 70%, which contains 50 % 2-butene gas, along with 20 % other low molecular weight derivatives of varying chain lengths. The dehydrogenation of polyethylene and its degradation were confirmed by the NMR, GC, GC-MS, Gel Permeation Chromatography (GPC), and Differential Scanning Calorimetry (DSC). The scope of our strategy was extended to many real-life post-consumer waste PE materials, yielding butene as the main product.



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Development of epoxy vitrimers from isosorbide epoxy resin and gallic acid

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The present world is facing various environmental and economic challenges stemming from plastic pollution and the exhaustion of fossil fuels[1]. Lack of recyclability, resistance to degradation, and dependency on non-renewable resources for material synthesis, are major drawbacks of the commercial polymers. Among them, thermosets contribute significantly to the category of non-recyclable plastics, due to their 3D crosslinked structure.

A strategy to synthesize reprocessable thermoset was proposed by Leibler and peers. His research suggested that incorporating dynamic chemical bonds in the thermoset matrix, makes it easily reprocessable. He also named this new class of materials as 'Vitrimers', as they soften and flow like glass at higher temperatures[2]. Vitrimers act like a conventional thermoset at the service temperatures and becomes malleable under a particular stimulus. This stimulus can be temperature, light or pH, which would lead to the topological rearrangements in the polymer matrix. To date, various vitrimeric systems have been developed ad studied using different dynamic bonds such as esters, disulfides, imines, acetals and boronic esters[3].

In this work, we have integrated vitrimer chemistry into bio derived epoxy resin ad harder, so as to synthesize a completely bio-based epoxy system. Here, we have used gallic acid, a phenolic compound, which is commercially produced from tannins or via the fermentation of glucose. Gallic acid was modified using maleic anhydride to induce to ester bonds. This modified gallic acid was cured with isosorbide-based epoxy resin, along with TBA catalyst to synthesize bio-based epoxy vitrimers. Two different systems with 20% and 30% hardener to epoxy ratio, were synthesized. The tensile and DMA studies revealed that the sample with 30% provided better thermo-mechanical properties. The material also displayed a shape shifting properties with 15s. The samples were also reprocessable into films from broken samples at 150^{O}C for 10 mins. Stress Relaxation studies also revealed that the activation energy for the transesterification reaction is within the limits for vitrimers.

Keywords: Thermosets, Vitrimers, Dynamic Bonds, Gallic Acid, Isosorbide.

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D-limonene loaded composite pea protein-konjac glucomannan aerogels for controlled *in-vitro* delivery in the gastrointestinal tract

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Bioaerogels have gained significant popularity in recent times for their biodegradability, high loading capacity, low thermal conductivities and high specific surface areas. Bioaerogels are fabricated by facilitating gelation of biopolymers to form a hydrogel, and effectively replacing the water in the gel with air[1]. Furthermore, plant protein is being viewed as a sustainable alternative to dairy and animal proteins in food systems, however, their poor gelling properties often limit their incorporation[2]. In such a scenario, proteins and polysaccharides can be composited to form an interconnected stable hydrogel network, and achieve the desired gelling, textural and rheological profile. In this study, pea protein and konjac glucomannan were heat-set under alkaline conditions, to form a self-supporting hydrogel3. A novel $scCO_2$ drying process was employed as an alternative to the freeze-drying process. While the freeze-drying process highly preserves the porosity, the expansion of the ice crystals during the freezing process and subsequent sublimation detrimentally affect the pore characteristics[4]. The hydrogels were subjected to a sequential solvent exchange in ethanolic solutions of increasing concentrations to form alcogels, which were dried using $scCO_2$ at varying pressures (100-200 bar) and temperature (55-65°C). The highest surface area of 97.38 $m^2\ g^{-1}$ was observed for aerogels, while the freeze- dried cryogel exhibited the highest pore diameter (22.17 nm). The aerogels exhibited excellent oil structuring and swelling, due to a greater pore volume and surface areas. Concomitantly, the optimized aerogel also exhibited a greater loading of D-limonene (5.01 mg/g), probably due to a greater oil absorption and oil holding capacity. The photo and thermal stability of D-limonene was enhanced, after loading on to the aerogel, in comparison to the free D-limonene. Interestingly while a burst release of D-limonene was observed in the cryogel within 4 h of immersion in the simulated gastrointestinal fluid, the aerogel (150 bar/55 °C) resulted in a more sustained *in-vitro* release of the same in the simulated intestinal fluid.

Keywords: Oleogel, Biopolymer, Supercritical carbon dioxide, controlled release

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Photoactivated Inverse Vulcanization of Benzoxazines: Toward High-Sulfur Copolymers with Enhanced Solubility and Reduced H_2S Emission

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Elemental sulfur is generated annually in tons globally. Despite this excess, there has not been much research done on the development of synthesis and processing techniques to transform elemental sulfur into different valuable products.[1] The development of organic polymers made from elemental sulfur (octa-cyclosulfur) using the inverse vulcanization reaction has attracted a lot of interest recently. Different with the traditional carbon-carbon based polymers, this kind of materials are based on sulfur-sulfur back bone, which naturally endows inverse vulcanized polymer many interesting properties the traditional polymer lacks, such as metal sensitivity, infrared insensitivity, dynamic adaptability, catalysis etc.[2] The harsh reaction condition and production of non-eco-friendly, hazardous by-products such as H_2S, poor processing and high loading of metal catalyst remain a major obstacles for this process. Also, the use of elevated temperature constrains the range of feasible crosslinkers. Herein, we report a photoinduced IV pathway for the synthesis of covalently bound organosulfur copolymers which gives flexibility for molecular architecture by incorporating reactive sites for more sulfur loading and use of bio-based precursors from a sustainable point of view. 1,3 benzoxazine act as reactive monomer and provide advantages over reported crosslinkers such as high thermal stability, structural engineering, good mechanical strength etc.[3] This approach enables high sulfur content copolymers with markedly improved solubility and almost negligible H_2S generation during synthesis, directly addressing two major limitations of conventional IV processes. The resulting benzoxazine–sulfur copolymers exhibit excellent electrochemical properties, including a specific capacitance of 512 F g^{-1} at 0.5 A g^{-1} and 97% capacitance retention after 2000 charge–discharge cycles in a 0.5 M H_2SO_4 electrolyte using a three-electrode system. This method not only facilitates the synthesis of advanced sulfur-based materials under mild conditions but also offers significant potential for sustainable energy storage applications.

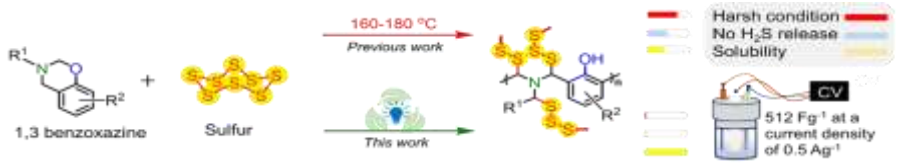


Figure 1. Novel methodologies for the synthesis of benzoxazine-sulfur copolymers.

Keywords: sulfur, inverse vulcanization, photo-irradiation, electrochemical, benzoxazines.

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Structural and morphological exploration of bamboo based nanocellulose

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Nanocellulose of different morphologies was extracted from bamboo fiber using acid hydrolysis. The work presented herewith includes the following; valorization of bamboo fibre for nanocellulose (NC) production followed with the effects of acid concentration on different morphologies of NC and its correlation with physical properties. Nanocellulose is extracted under three different concentrations of H_2SO_4 : 48 %, 64 %, and 72 %. Purified nanocellulose was characterized by Scanning Electron Microscopy (FE-SEM), Atomic Force Microscopy (AFM), Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM) and Thermogravimetric Analysis (TGA). AFM, TEM and FE-SEM confirmed the production of three different morphologies of nano cellulose. The NC-48 had a web-like structure typically observed for cellulose nanofibrils (CNF), whereas NC-64 were observed as cellulose nanocrystals (CNC) with rod-like shapes, respectively, and NC-72 displayed spherical particles termed cellulose nanospheres (CNS). The total crystallinity index of NC was calculated using FTIR, and a similar trend of crystallinity was also observed from XRD analysis. NC-48 was obtained with the highest yield of 81.83 %, followed by 70.80 % NC-64, respectively, whereas NC-72 yielded the lowest yield of 14.03 %. NC-72 had the highest thermal stability among other NC morphologies. We report a cost effective and feasible approach of utilizing inexpensive bioresources for production of value added products like nanocellulose, which could find potential application in the fields of packaging [1].

Keywords: Lignocellulosic biomass, Chemically purified cellulose, Nanocellulose, Acid hydrolysis.

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Stimuli-Gated Polynorbornene Micelles: Integrating Photo-responsive Morphodynamics with Selective Bio-analyte Recognition and Molecular Cryptography

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Engineering polymers capable of executing multiple, orthogonal stimuli-responsive behaviours within a single molecular framework represents a frontier in smart materials design. In this work, we present a multifunctional polynorbornene-based homopolymer synthesized via ring-opening metathesis polymerization (ROMP) that simultaneously integrates dual-mode chemical sensing, photoinduced nano structural modulation, and optical data encoding. Each repeating unit incorporates two complementary chromophores: a naphthalimide moiety, conferring selective nucleophile reactivity and strong fluorescence, and an azo functionality, providing redox and photochemical responsiveness, resulting in a uniformly functionalized polymer backbone with precise reactivity. The polymer exhibits orthogonal chemical selectivity, where hydrazine triggers a visible chromogenic response via naphthalimide, and sodium dithionite induces selective azo cleavage, producing a pronounced fluorescence "turn-on." Upon UV irradiation, trans–cis isomerization of the azo units perturbs noncovalent interactions, driving measurable morphological rearrangements from spherical to oval in self-assembled nanostructures. Additionally, the material facilitates optical writing and information encoding, revealing concealed patterns under UV illumination. This study establishes a novel molecular design paradigm for ROMP-derived homopolymers, where the strategic integration of complementary chromophores enables precise, multifunctional, and predictable responses to chemical and photonic stimuli, providing a versatile platform for advanced sensing, diagnostics, and light-controlled functional materials.

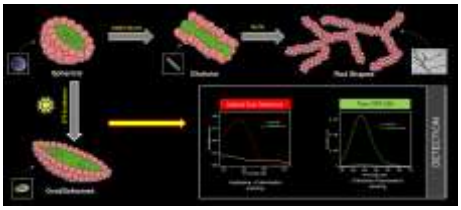


Figure 1. Highlights of the present work.

Figure 1. Highlights of the present work.

Keywords: Stimuli-Responsive Polymer; Polynorbornene; Ring-Opening Metathesis Polymerization (ROMP); Photo-responsive Material; Chemical Sensing.

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Linseed oil based non-isocyanate poly urethane coatings for anticorrosion applications

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Epoxy and polyurethane-based coatings are now often used as protective coating materials. Traditionally, isocyanates—which are hazardous to both humans and animals and are categorized as carcinogens—are used to make polyurethane materials. The landfill's isocyanate concentration rises. Furthermore, these polymers are hazardous to the environment because they require the usage of volatile organic compounds (VOCs) as solvents in order to retain their fluidity. One kind of hydrocarbons derived from plants that can be used as a substitute for conventional hydrocarbons is vegetable oils (VOs) [1]. They possess several advantageous qualities such as being non-toxic, reasonably inexpensive, biodegradable, and renewable. Vegetable oils (VOs) usually contain ester sites, hydroxyl groups, and double bonds. These can be changed to create polymers that are appropriate for coating applications. Epoxidized vegetable oils (EVO) can be modified by CO_2 fixation under high pressure to yield non-isocyanate polyurethanes (NIPU). These NIPUs can be conveniently cured at room temperature [2]. The objective of this study was to examine the use of CELO (Cyclic Carbonate Epoxidized Linseed Oil) based NIPU and its nanocomposites as corrosion protection coatings. Tri ethylene tetraamine (TETA) was used as a curing agent and deposited onto aluminum substrates at ambient temperature. The coatings were examined using FTIR, FESEM, contact angle goniometer, and TG-DTA. Polarization and electrochemical impedance spectroscopy (EIS) studies were conducted to gain further insights into the corrosion characteristics of the material. The formation of bonds are depicted through FTIR. FESEM images shows the wriinkle shaped morphology, contact angle shows the hydrophobic nature. The improvement in corrosion resistance can be seen from EIS plots.

Keywords: Bio-based, Anti-corrosion, Non-toxic, Linseed oil.

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Self-Healable and Reprocessable EPDM Elastomer via Dual Dynamic Cross-Links

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Covalently cross-linked elastomers are widely recognised for their excellent elasticity, which makes them essential for a number of applications such as medical implants, tires, seals etc.[1] It is extremely desired to develop flexible and self-healing rubbers since they are capable of being reprocessed to increase their lifespan and reduce environmental pollution.[2] This work demonstrates a straightforward approach to develop mechanically resilient, healable, and recyclable elastomeric vitrimer based on EPDM (ethylene propylene diene monomer rubber). This was accomplished by using a dynamic dual cross-linker, which can induce disulphide metathesis as well as transesterification reactions in epoxidized EPDM. In this case, the EPDM was epoxidised to prepare E-EPDM by using meta-chloroperoxybenzoic acid (mCPBA) as an epoxidising agent. The epoxidation of EPDM is confirmed by ^{1}H-NMR and FT-IR analyses. The dynamic dual cross-linker with disulphide linkage bearing dicarboxylic groups, i.e., (4,4'-((disulfanediylbis(4,1-phenylene))bis(azanediyl))bis[4-oxobutanoic acid] (BBO)) was synthesized by reacting of 4-aminophenyl disulphide and succinic anhydride in DMF solvent at ambient temperature under inert atmosphere. The formation of cross-linker was confirmed by ^{1}H-NMR, MALDI-TOF, and FT-IR analyses. The epoxy group of E-EPDM reacted with dicarboxylic groups in BBO to form β-hydroxy ester functional groups, which undergo exchange reaction. This exchange reaction along with the metathesis reaction of disulphide present in BBO installs mechanical resilience, self-healing, and reprocessibility in the modified EPDM.

Keywords: Dynamic dual cross-links, Transesterification, Metathesis, Self-healing, Reprocessibility.

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Sustainable economic packaging for post-harvest storage and transport of Khasi Mandarin

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Sustainable Approach: Sustainable packaging plays a vital role in protecting products from mechanical damage, physiological losses, and microbial infestation. In this study, Khasi Mandarin was coated with an edible formulation of guar gum (0.2 %): chitosan (0.2 %) and stored in the lab-made compostable packaging manufactured from PLA and PBAT (70:30). This combined approach maintained the physicochemical properties of the Khasi Mandarin for over 50 days at ambient conditions (25 ± 5 °C, RH 75 ± 5 %) (Goswami et al., 2024). The edible coating helped reduce the microbial infection and physiological loss, whereas the secondary packaging, designed to keep each mandarin separate, prevented browning, and dryness. Hence, only 13% physiological weight loss, 11% change in total soluble solids, and 1.5 N reduction in firmness were observed. Unlike paper or cloth packaging, the designed PLA-PBAT boxes were impermeable to air and moisture, which helped address the common problems of weight loss and dryness.
Economical approach: The developed approach is also economical: one liter of the developed edible coating formulation is ₹119.60, which is sufficient to treat 150 Kg of mandarins. The cost of each lab-made injection-molded box is approximately ₹46.40, could store four Mandarins These findings demonstrate a sustainable and cost-effective method for extending the shelf-life of Khasi Mandarin during storage and transportation.



Figures 1 – a) Effect of edible coating (primary packaging) on the storage of Khasi Mandarin up to 20 days. b) Effect of compostable box packaging (secondary packaging) on the storability of coated mandarins, compared with uncoated Mandarin and Mandarin treated with commercial coating solution for up to 50 days.

Keywords: Edible coating, Primary packaging, Secondary packaging, Storability, Shelf life.

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Argon Plasma Assisted Biofilm Colonization on Poly(L-Lactic acid)/ Polyhydroxyalkanoate- Cast film for Enhanced Soil Biodegradation

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Surface of Poly(L-lactic acid) (PLA), Poly(3-hydroxybutyrate-co-3-hydroxyhexanoate) (PHBHHx) and their cast film blends were activated using low-temperature argon-plasma to confirm the possibility of improved microbial adhesion and biodegradation rate using soil microflora as degrading medium. Radio frequency (RF) plasma system selectively altered the surface characteristics of PLA/PHBHHx blend cast films without significantly affecting their bulk properties. Notably, Ar-etching (12 min, 50W) promoted a strong hydrophilic behaviour (up to 25º ± 2º), surface energy (up to 48% ± 5%), and surface roughness by ~4 fold. Increased wettability on plasma-treated samples could be linked to the introduction of polar group (C−O and O=C−O) and formation of distinct rough topographical structures which provides conducive microenvironment for initial microbial attachment and subsequent biofilm formation. Enhanced wettability favors abiotic hydrolysis by promoting biofilm formation (30% ± 5%) which in turn stimulated biodegradation rate by 1.1-1.5-fold. These findings indicate that surface activation by argon plasma is a sustainable and viable strategy to enhance cell- surface interaction and biodegradation of biopolymers.

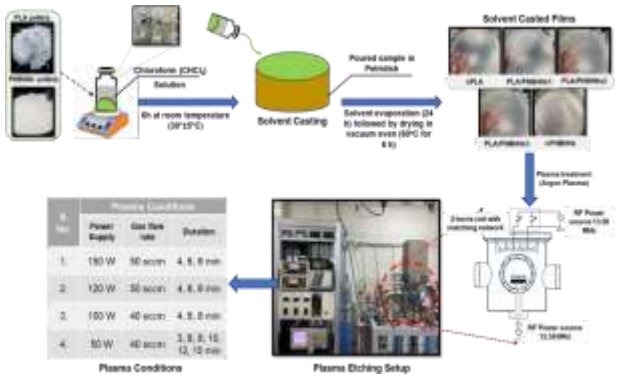


Figure 1 – Plasma etching treatment setup and schematic diagram of the process.

Keywords: Plasma treatment; Wettability; Biopolymers; Biofilm formation; Biodegradation.

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PCL-coating in Paper Substrates for Realizing Colorimetric Sensing Platforms to Detect Selected Health Risk Biomarkers

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Paper-based devices are increasingly being explored as economical and eco-friendly substitutes for traditional assay platforms. In this study, we developed a polycaprolactone (PCL) coated paper platform for colorimetric detection of health-related biomarkers. The device was fabricated using a screen-printing method, and hydrophobic barriers were introduced by incorporating a PCL solution. Their successful formation was confirmed through solvent testing along with characterization by optical microscopy, FTIR, and SEM. The PCL layer provided mechanical stability and uniform test zones, which improved the reliability of colorimetric measurements. The performance of the device was assessed using various analytes, including glutathione (GSH), glucose, arsenic (III), and bovine serum albumin (BSA). The analytes were analyzed using both lab instruments and rapid image-based analysis at their optimal detection wavelength and RGB channels, respectively. A strong linear response with concentration was achieved from both techniques ($R^2 > 0.96$). Low detection limits were obtained, indicating good sensitivity and reproducibility. Overall, the PCL-coated paper device demonstrates a simple and disposable platform suitable for spectroscopic analysis of clinically relevant biomarkers. Its stability, reproducibility, and ease of fabrication make it a promising tool for bioanalytical and diagnostic applications.

Keywords: polycaprolactone (PCL), glucose, glutathione, arsenic (III), bovine serum albumin.

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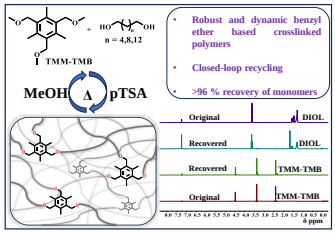
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Closed-loop recyclable cross-linked polymeric materials via dynamic transetherification

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The linear polymer economy (take-make-dispose) has resulted in enormous polymer pollution and loss of energy embedded within these macromolecules. The closed-loop chemical recycling, which involves the regeneration of the original polymer from the recycled monomers, addresses these challenges associated with polymer pollution by enabling the recovery and reuse of polymers.[1] However, unlike linear polymers, achieving closed-loop recycling of crosslinked polymers, widely used across various industries for their advantageous thermal and mechanical properties, remains a significant challenge. More recently, the closed-loop recycling of the thermoset polymers has been achieved via the incorporation of dynamic covalent motifs such as diketoenamine exchange, imine formation, transesterification, transimination, and reversible amidation. Despite these advancements, the range of dynamic covalent chemistries used to design the closed-loop recyclable crosslinked polymers remains narrow compared to the broad spectrum of available dynamic chemical reactions. Furthermore, designing dynamic chemistries that simultaneously offer effective bonding, robustness, and reversible cleavage for monomer generation remains a major challenge in achieving closed-loop recyclability.



To address these challenges, we have designed the closed-loop recyclable crosslinked polymer using our recently developed transetherification as robust and dynamic covalent chemistry (Fig.1).[2,3] The crosslinked polymers were prepared by the solvent-free melt transetherification route employing a tri-benzyl ether monomer (TMM-TMB) and the diol. A series of polymers was prepared by systematically varying the diol chain length by four methylene units, and the effect of crosslink density on the thermo-mechanical and dynamic properties of the networks was examined. Owing to the presence of the robust ether linkages, the polymers demonstrated excellent thermal and chemical stability. The dynamic ether linkages enable the reprocessability of the crosslinked polymers. Notably, the dynamicity of these polymers was shown to be regulated by the diol chain length. Impressively, to achieve the closed-loop recyclability, the polymers were chemically degraded using excess methanol, and monomers were recovered in high purity and yield. The recovered monomers were used to regenerate the polymers with near retention of their original properties.

Keywords: Closed-loop recycling, transetherification, recyclable thermoset, tunable dynamicity.

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Enhancing the Storability of Thompson Seedless Grapes using Xanthan Gum–Based Edible Coating Enriched with Grape Stalk Extract

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This research aimed to develop an edible coating based on xanthan gum incorporated with grape stalk extract (GSE) with varying concentrations (5–25%) and evaluate its potential to enhance the storability of white grapes under ambient conditions. The GSE demonstrated a high phenolic content (259.81 mg GAE/g) and flavonoids (16.52 mg QE/g) as well as excellent antioxidant activity (95.73%). The edible coating incorporated with a GSE content of 25% (XG-GSE-25) demonstrated excellent phenolic and antioxidant activity. The application of edible coating on white grapes retained the quality attributes during storage at ambient conditions such as reduced weight loss (24.97%) control with minimal changes in puncture strength (~20%), titratable acidity (~22%), total soluble solids (~19%), ascorbic acid content (~17%), membrane electrolytic leakage (~36%), respiration rate (~2.4 mg CO2 kg^{-1} h), and color attributes as compared to control up to 16 days. Further, the developed coating with high GSE concentration was effective in retaining the phenols, flavonoids, and antioxidant activity of grapes compared to that of uncoated grapes.

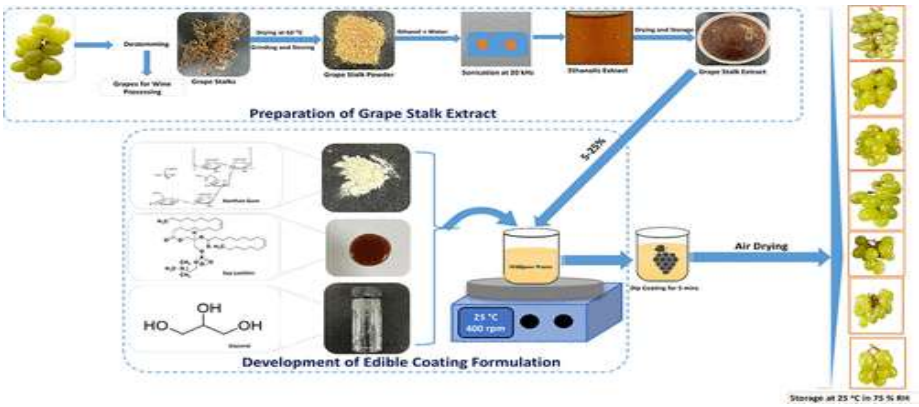


Figure 1 – Development and application of edible coating formulation enriched with GSE.

Keywords: Grape stalk extract, Xanthan gum, Edible coating, Shelf life, Antioxidant activity.

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Biomass-Derived Nitrogen-Doped Carbon Dots for Dual Sensing of Co^{2+} and Nitric Oxide with Bioimaging Applications

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Biomass-derived carbon dots (CDs) represent a sustainable platform for nanomaterial synthesis; however, their intrinsic photoluminescence is often limited.[1] Fluorescent carbon dots (CDs) can function as colorimetric sensors when they are exposed to external stimuli like acid and metal ions. Because of their chemical stability, biocompatibility, customizable photoluminescence, photobleaching resistance, and simplicity of synthesis, these CDs have the potential to replace conventional methods due there onsite, easy, and economically viable detection.[2, 3] In this work, a green and cost-effective hydrothermal route was employed to synthesize nitrogen-doped carbon dots (NCDs) using agricultural residues as carbon precursors and amine-rich biomass waste as the nitrogen source. The as-prepared NCDs displayed enhanced fluorescence emission compared to nondoped CDs, along with excellent aqueous dispersibility, high photostability, broad pH tolerance (2–12), low cytotoxicity, and superior biocompatibility. The NCDs exhibited remarkable selectivity and sensitivity toward cobalt (II) ions, achieving a detection limit of 39.8 nM via fluorescence quenching, which could be efficiently reversed by the addition of EDTA. Furthermore, the NCDs enabled nitric oxide (NO) sensing with a detection limit of 53.2 μM, highlighting their applicability for monitoring biologically relevant signaling molecules. Density functional theory (DFT) calculations supported experimental findings by elucidating the role of nitrogen doping in modulating the electronic structure and optical properties. Owing to their efficient cellular uptake and negligible cytotoxicity, the NCDs were further demonstrated as promising candidates for bioimaging applications.

Keywords: Carbon dots; metal ion sensing; biomass; bioimaging.

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Extraction of nanomaterials from agricultural waste residue and its application in the construction industry

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Stubble burning is one of the prime origins of ever-growing air pollution in south-Asian countries [1]. One of the best ways to tackle this problem is to utilize extracted biomaterials from agro-waste to valorize them for further economic benefits [2]. Here, cellulose, lignin, and silica were extracted separately from raw rice husk waste and wheat straw. Dimethyl Sulfoxide (DMSO) treatment has been incorporated to solve the coprecipitation issue of silica and lignin. Quantitative analysis concludes around 79.71%, 52.84%, and 60.79 % yield for the cellulose, lignin, and silica components, respectively. Qualitative analysis reveals the purity of each component. Morphological data confirm the successful conversion of all extracted biomaterials into nano-dimensioned forms. Extracted cellulose has numerous applications in the insulation and packaging fields and as a reinforcement in composites, while lignin is increasingly popular for fabricating adhesive and water-resistant coatings [3]. On the other hand, silica nanoparticles are renowned for their applications in electronic devices, semiconductors, acoustic insulation, etc. In the present study, we have demonstrated one such application from extracted Lignocellulosic Biomass (LCB) components. Here, a comparative study was made on the fabricated cement composite using cellulose nanofibers (CNF) and TEMPO-oxidized CNF [4]. A modification using CNF was found extremely useful in developing early strength in the cement composite; an increase of 17.6% of compressive strength and 22.6% of tensile strength was observed at 0.01 wt% CNF dose after 3 days, a similar trend was also observed at the end of 7 and 28 days. Further enhancement in mechanical properties was checked by varying the ratio of CNF to TEMPO-CNF at 0.01 wt% loading. A 1:1 mixture of CNF and TEMPO-CNF was found to uplift the compressive and tensile strength at most. Apart from mechanical properties, other features like morphology, thermal conductivity, and water absorption capacity have been improved, besides making the composite lighter in weight with higher porosity and lower density. The results motivated us to use these sustainable and eco-friendly biomaterials to fabricate more advanced functional materials for high-end applications, as discussed earlier.

Keywords: Cellulose nanofibers, Silica nanoparticles, Lignin nanoparticles, Extraction, Cement Composite.

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High-Performance Bio-Based Composites from Vegetable Oil Resin and Hyperbranched Tannic Acid-Methacrylate Derivative

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Tannic acid's (TA) bulky, branched structure leads to steric hindrance, limiting the accessibility of its hydroxyl groups for reactions with resin and fiber surfaces.[1] With a view to overcoming this limitation and developing high-performance bio-based composites with enhanced functionality, methacrylic anhydride-modified epoxidized linseed soybean oil (MAELSO), a bio-based resin, was combined with a novel tannic acid-glycidyl methacrylate derivative (TAGMA). TAGMA was synthesized via a ring-opening reaction between the epoxy groups of glycidyl methacrylate (GMA) and the hydroxyl groups of TA, while the residual vinyl groups remained available for subsequent polymerization.[2] The resulting hyperbranched TAGMA was incorporated into the MAELSO matrix and further reinforced with coconut fibers (CF) to obtain sustainable bio-based polymer composites. Nuclear magnetic resonance (NMR) spectroscopy confirmed the successful synthesis of TAGMA, while Fourier transform infrared (FTIR) spectroscopy revealed strong interfacial interactions among the composite constituents. The composites were systematically evaluated for their mechanical, thermal and flame-retardant properties. Results demonstrated that incorporation of TAGMA significantly enhanced hardness, tensile strength and flexural strength, which could be attributed to the improved crosslinking density and hyperbranched architecture. This work thus presented an efficient strategy for designing sustainable, high-performance composites by exploiting multifunctional tannic acid derivatives and renewable feedstocks.

Keywords: Bio-based composites; Coconut fibers; Hyperbranched methacrylates; Mechanical properties; Ring-opening polymerization.

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ROPISA Strategy for In-situ Encapsulation of Cargoes for Biomedical Application

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The aqueous self-assembly of polymers is traditionally accomplished in the post-polymerization stage by various techniques such as nano-precipitation to prepare several nano-objects for biomedical application. The self-assembly processes are typically performed under very dilute conditions; thus, the scalability become difficult for large-scale industrial applications. To overcome this issue, polymerization- induced self-assembly (PISA) methodology is developed to directly create polymer nano-objects while synthesizing them in water or water + organic solvent mixtures. Typically, the PISA in water involves the chain extension of soluble hydrophilic macroinitiator by insoluble hydrophobic monomer resulting in the formation of amphiphilic block copolymer that simultaneously grows and self-assembles. Synthetic polypeptides are important polymers mimicking protein-like secondary structures, and they are typically produced via ring opening polymerization (ROP) of N-carboxy anhydride (NCA) monomers derived from L-amino acid bio- resources using amine initiators in dry organic solvents. In the last 2-3 years, the ROP process is coupled with PISA (named ROPISA) for the polymerization of water insoluble NCA monomers in aqueous medium using water soluble PEGylated amine as initiator to produce self-assembled nano-formulations.[1-2] This ROPISA route open up unprecedented opportunity for synthetic polypeptides, in general, and the resultant amphiphilic block copolymers could be directly used for diverse application in both material and biomedical field. Our group is engaged in developing synthetic strategies to access unexplored high molecular weight β-sheet polypeptides and their block copolymers by steric-hindrance assisted ROP process.[3-4] To expand the scope of the emerging ROPISA strategy to β-sheet polypeptides, recently we have report an elegant in-situ ROPISA strategy for fluorescent dye encapsulation strategy in poly(L-serine)[5] and this process is also expanded to poly(*L-tyrosine)* based nanoparticles in aqueous medium. In this process, the ROPISA was established in the presence of fluorescent dyes and other biological relevant molecules so that the resultant stable emulsion nanoparticles could be directly used for biomedical application. The degree of polymerization was optimized at 20-25 units, and the SEC chromatograms showed narrow molecular weight polymers. The stable polypeptide emulsions were subjected to DLS analysis and it revealed the existence of nano-assemblies of sizes around 20 to 30 nm and these nano-assemblies were found to be spherical nanoparticle objects based on our FE-SEM, HR-TEM and AFM analysis. Using this approach, in-situ encapsulation of three dyes (HPTS, Nile Red, and Rhodamine B) were successfully carried out by adding dye in the beginning of polymerization. The biocompatibility of nascent polymer emulsion and dye loaded polymer emulsions were found to be non-toxic to mammalian cells. Additionally, nascent polymer emulsion was found to be non-hemolytic to RBCs indicating its biocompatible nature. Confocal microscopy-based imaging assay revealed successful time dependent uptake of Nile red loaded polymer nanoparticles by mammalian cells. This green chemical approach of making polypeptide nano-formulations expand their boundaries for variety of guest molecules like anticancer, antimicrobial and anti-inflammatory drug molecules in biomedical applications.

Keywords: PISA, ROPISA, Fluorescent Probe, Polypeptides, Bio-imaging, and Drug Delivery.

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Cellulose Nanocrystals Reinforced Chitosan Hydrogel as Controlled-release Phosphorous Fertilizer in Smart Agriculture

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The growing global demands for food security, efficient nutrient utilization, and environmentally resilient agricultural practices highlight the need for sustainable alternatives to conventional farming inputs. Traditional fertilizer application often leads to nutrient leaching, low use efficiency, and environmental degradation [(1,2)]. Smart hydrogels, with their tunable physicochemical properties, have emerged as promising candidates to address these issues by providing controlled nutrient release and improving water use efficiency [(3)]. In this study, we have developed hybrid hydrogels based on crosslinked networks of chitosan (CH) and cellulose nanocrystals (CNCs) for the controlled-release of di-ammonium phosphate (DAP) fertilizer (P- fertilizer). The hybrid hydrogels with different compositions were prepared by varying either the crosslinker amount or the CNC loading. We optimized the final hydrogel composition after evaluating several physicochemical properties such as morphological, rheological, thermal, swelling, water retention, and porosity. The incorporation of CNCs in the CH hydrogels was found to significantly improve mechanical stability, swelling behavior, and pore structure of the hydrogel network. The swelling index of DAP-loaded CNC-reinforced hydrogels reached as high as ~ 3000%, as compared to ~ 1750% for CH hydrogels without CNC loading. The cumulative phosphate release study was conducted using DAP-loaded hybrid hydrogels immersed in water, where phosphate release was monitored over 15 days. The incorporation of CNCs in the hybrid hydrogels provided a more sustained and regulated phosphate release profile compared to DAP- loaded pristine CH hydrogels. We obtained approx. 27% phosphate release within the first 6 hours, which gradually reaches ~ 60% after 288 hours, indicating a balanced combination of initial availability and sustained long-term release of P-fertilizer. On the other hand, the pristine CH hydrogels released only ~ 20% initially and reached merely ~ 45% after 288 hours followed by equilibrium, thus showing their comparatively lower and less efficient release capacity. Hence, the controlled-release behavior of hybrid hydrogels highlights the role of CNC in strengthening the hydrogel network and enabling prolonged fertilizer delivery for phosphorus management in modern agriculture, contributing toward resource-efficient crop production.



Figure 1- Schematic of CNC reinforced chitosan hydrogel for controlled-release of fertilizer.

Keyword: Cellulose Nanocrystal, Sustainable Agriculture, Controlled-release Fertilizer Hydrogels.

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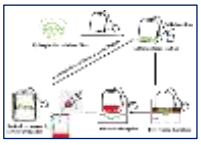
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Surface Modified Cellulose Fibers-based Natural Sorbents for Oil/Water Separation

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Oil–water separation remains a pressing environmental challenge, and the development of sorbent materials that are not only efficient but also sustainable and reusable for oil–water separation is environmental priority [1,2,3]. In this work, cellulose fibers (CFs) were extracted from waste orange peel biomass and subsequently surface modified with silane to impart hydrophobicity. The modified CFs were deployed inside standard tea bags, which were immersed in oil–water mixture for one minute without any external force, allowing oil adsorption by capillary and surface-driven forces. This simple, reproducible method enabled a practical evaluation of sorption efficiency under static conditions. The performance of hydrophobic CFs was tested using different oils, including diesel, decane, and dodecane, to demonstrate versatility. Rapid sorption was observed, with complete oil removal in one minute from different oil-water mixtures at an optimized dosage.
aterial characterizations confirmed the successful modification and functional stability of the CFs. AFM imaging revealed clear fibrillar morphology with an average fiber width of ~ 0.21 µm, providing a fibrous texture favorable for sorption. Water contact angle of 126 ± 0.352° was achieved, confirming strong hydrophobicity after silane functionalization. FTIR spectra displayed characteristic Si–O–C and C–H stretching vibrations, verifying surface modification, while XRD confirmed the cellulose phase and silane modification. Importantly, FTIR and XRD analysis performed on the sorbent material after decane oil sorption showed that the chemical structure and morphology of the material were retained, indicating material stability during oil/water sorption study. We further confirmed the successful sorption of oil from oil/water mixture via fluorescence microscopy performed on the hydrophobic fiber. Reusability tests demonstrated appreciable retention of sorption capacity over three cycles. Hence, this work highlights a simple strategy for converting biomass-derived fibers into functional hydrophobic sorbents. The practical tea bag deployment method underscores their potential for scalable application in oily wastewater treatment and oil spill remediation.



Figures 1- Graphical abstract of sorption test and regeneration procedure.

Keywords: Cellulose fibers, Sustainability, Oil–water separation, Wettability.

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Chromium treated Kombucha cellulose as a Leather alternative

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Cellulose-based materials are important for different applications covering textiles to medical bandages[1]. Very recently, cellulose derived materials, particularly materials from Kombucha-derived bacterial cellulose have been used as leather-like materials. Those materials are considered as sustainable because of their environment-friendly natures, biodegradability and non-toxicity[2]. However, pristine cellulose like Kombucha-derived cellulose cannot be used directly as leather-like materials as they are brittle and crumble like paper when dried. The modification of bacterial cellulose is driven by the need to overcome its inherent limitations while enhancing its properties for diverse applications[3]. Hence, first the chemical modification of bacterial cellulose was achieved with chloroacetic acid. Later, the oxidized bacterial cellulose had been allowed to interact with chromium sulphate where non-covalent bonding with carboxymethyl cellulose and chromium can take place, further, the Chrome treated Kombucha bacterial cellulose was subjected to post-tanning process to improve the physical and mechanical properties. Various spectroscopic techniques like FTIR and ICPOES were used for the confirmation of the reactions. The surface wettability was studied by contact angle meter. DSC showed the thermal behaviour. XPS analysis was performed to confirm the non-covalent bonding of chromium and carboxymethyl cellulose chromium bonded with carboxymethyl group. The pristine BC and the modified BC was subjected to physical strength measurements where the modified BC showed substantial increase in tensile strength, elongation at break and water-vapor permeability. These results suggest chrome-treated Bacterial cellulose pellicle from Kombucha as a sustainable leather-like alternative.

Keywords: Kombucha, Bacterial Cellulose, Leather-like, Chrome-tanning.

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Smart UCST Polymers for Catalysis: PNAGA–Cu(I) as a Thermoresponsive Recyclable Catalyst

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Thermoresponsive polymers offer an effective strategy for controlling catalyst solubility, activity, and recyclability by simply adjusting the temperature. In this study, we report the synthesis of a copper(I) complex derived from poly (N-acryloyl glycinamide) (PNAGA)[1], a polymer that exhibits upper critical solution temperature (UCST) behavior in water, and its application as a recyclable catalyst for azide–alkyne cycloaddition (CuAAC) "click" reactions [2, 3]. To create a stable polymer–metal complex, PNAGA was synthesized via controlled radical polymerization[4] and subsequently coordinated with Cu(I). Owing to the UCST nature of PNAGA, the catalyst displayed reversible solubility switching, which enabled facile recovery and separation from the reaction medium. Under mild conditions, catalytic experiments using model azide and alkyne substrates afforded highly efficient and selective synthesis of 1,2,3-triazoles. Moreover, the PNAGA– Cu(I) catalyst demonstrated excellent stability and reusability, retaining high activity over multiple recycling runs. The catalyst was used for successful click reaction on bacterial cellulose material for preparing leather- like material. Overall, this work highlights the potential of integrating smart polymers with transition-metal catalysis and establishes PNAGA–Cu(I) complexes as efficient and sustainable catalysts[5] for click chemistry.

Keywords: Thermoresponsive polymers Click Chemistry Recyclable catalysis.

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Sustainable Epoxidized Natural Rubber-based Vitrimeric Elastomer via Imine and Acetal Metathesis Reactions

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Advancements in sustainable dynamic polymer networks remain a critical yet challenging pursuit in polymer science, despite the extensive industrial relevance of these materials. Conventional elastomeric compounds often conflict with core principles of green chemistry, as they are typically derived from petroleum-based rubbers, incorporate toxic additives, and feature irreversible crosslinked structures that limit recyclability and reusability. This study employed bio-based epoxidized natural rubber (ENR) to construct a dual dynamic network utilising imine and acetal metathesis chemistries. The bio-derived protocatechualdehyde (3,4-dihydroxybenzaldehyde, DHB) was first converted into a Schiff base through reaction with para-phenylenediamine. Functionalization of ENR with this modified DHB moiety (DHB-PA) introduced dynamic imine bonds and catechol functionalities into the polymer backbone. Subsequently, the catechol groups were further crosslinked with 1,4-benzene dicarboxaldehyde (BDA) via dynamic acetal linkages, yielding a recyclable and reprocessable elastomeric network. The combined presence of imine and acetal bonds imparted rapid stress relaxation at elevated temperatures, enabling recyclability and efficient reprocessability. Additionally, the material exhibited acid and heat-triggered chemical degradability and demonstrated an excellent self-healing efficiency of 89%. These findings present a novel strategy for constructing green, repairable, and chemically recyclable rubber networks by harnessing bio-derived components and dynamic covalent chemistry.

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Intelligent Amphiphilic Diblock Copolymer for Dye and Heavy Metal Removal

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Growing concerns about organic dye pollution and heavy metal contamination in aquatic systems have driven the need for advanced polymer-based solutions.[1] In this work, we report the design and development of an amphiphilic diblock copolymer, poly(methacrylic acid)-*block*-poly(trifluoroethyl methacrylate) ($PMAA_{20}$-*b*-$PTFEMA_{15}$), tailored for dye encapsulation and metal ion removal (Figure 1). The synthesis was carried out through ultrasmall sulfur-dots-assisted[2] photo-induced reversible deactivation radical polymerization (photoRDRP), which allowed precise control over the molecular structure of *tert*-butyl methacrylate (TBMA). Subsequent chain extension with 2,2,2-trifluoroethyl methacrylate (TFEMA), followed by selective hydrolysis of the poly(*tert*-butyl methacrylate) block, generated $PMAA_{20}$-*b*-$PTFEMA_{15}$. This transformation introduced hydrophilic carboxyl functionalities while maintaining the unique characteristics of the fluorinated segment. Owing to its amphiphilic architecture, the copolymer efficiently adsorbed and encapsulated both hydrophobic dye (Coumarin 102) and hydrophilic dyes (Eosin B, Congo Red) via combined electrostatic and hydrophobic interactions. In addition, strong coordination between the carboxyl groups and Pb^{2+} ions enabled effective metal ion chelation. These findings highlight the potential of this functional copolymer as a versatile platform for water purification, contaminant sensing, and imaging-related applications.[3]

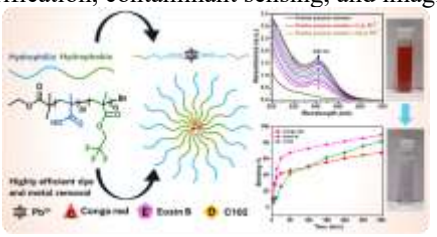


Figure 1. Synthesis of an amphiphilic diblock copolymer, $PMAA_{20}$-*b*-$PTFEMA_{15}$, via S-dots mediated photoRDRP. It further investigates binding and encapsulating dyes such as Eosin B, Congo Red, and Coumarin C102, as well as its capacity for Pb^{2+} removal from wastewater.

Keywords: stimuli-responsive polymer, photopolymerization, dye binding, heavy metal removal, environmental remediation.

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Emulsion Polymerization via Ultrasonic Process: A Green and Sustainable Approach

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Styrene and acrylic copolymers are extensively used in adhesives, paints, and coatings[1]. Traditionally, these polymers are prepared via emulsion as well as solution process using chemical initiators[2]. In present era, polymer chemists are very much keen to make greener synthesis processes using different sustainable approaches. Polymerization via ultrasound does not need any chemical initiators[3]. Ultrasound-assisted emulsion polymerization is an important approach toward sustainability[4].

In this investigation, polystyrene-*co*-butyl acrylate was prepared by sono-emulsion polymerization (SEP) as well as conventional emulsion polymerization (CEP) and the resulting polymers were characterized through NMR and FTIR analyses. The SEP process demonstrated several notable advantages over the conventional approach, including a higher polymerization rate, the formation of polymers with higher molecular weight and lower dispersity, and the production of latex particles with smaller diameters. These features contribute to improved mechanical and adhesive properties in the resulting polymer. Interestingly, SEP operates efficiently at room temperature and eliminates the need for chemical initiators, making it a more sustainable and greener process. However, the SEP process is highly sensitive to factors such as ultrasound frequency, power input, monomer concentration, monomer vapour pressure, and reactor design, which complicates optimization.

Keywords: Acrylate copolymer, Emulsion, Ultrasonic, Green, Sustainable.

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Chemical Crosslinker Free Bio-derived Porous Hydrogels for Organic Dye Removal from Wastewater

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Industrial wastewater containing toxic dye effluents poses severe environmental and health hazards, including genotoxic, cardiotoxic, immunotoxic, and reproductive system damage.[1] Adsorption is among the most effective and low-cost dye removal techniques, with hydrogels being particularly attractive due to their high surface area with its 3D networks. However, many hydrogels are petroleum based, nonbiodegradable, and require chemical crosslinkers, catalysts, or elevated temperatures, leading to ecological toxicity, high costs, and scalability issues. In this study, we present sustainable, rapid gelation of acrylamide (AAm) at ambient temperature, without any chemical crosslinkers or catalyst, for the removal of both cationic and anionic dyes (Figure 1). Spontaneous amino acid derived porous hydrogels were synthesized using random copolymer of N-methacryloyl-(L)-glutamic acid (MAGA) and N,N-dimethylaminoethyl methacrylate (DMAEMA) or N,N-dimethylacrylamide (DMA), which initiated gelation of AAm through persulfate activation. The resulting poly(DMAEMA-*r*-MAGA)/PAAm and poly(DMA-*r*-MAGA)/PAAm composite hydrogels exhibited tunable porous structures, excellent structural integrity, and high dye adsorption efficiency toward Eosin B, Methyl orange, and Rhodamine B. This material offers a cost-effective and scalable solution with significant potential for broader environmental applications. Their ability to be mold-printed highlights their potential in sustainable wastewater treatment and 3D printed environmental remediation devices.

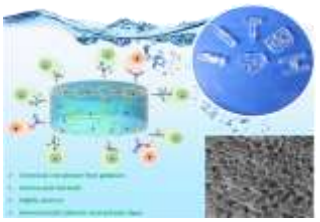


Figure 1: Schematic representation of highly porous mold printable composite hydrogels for dye removal application.

Keywords: chemical crosslinker free gelation, amino acid-derived hydrogel, porous hydrogel, organic pollutants removal, wastewater treatment.

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Crafting tailored, well-defined block copolymers of cyclic esters with an organomagnesium initiator

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An organomagnesium complex containing an imino-phosphanamidinate ligand was reported. The organomagnesium complex was found to be a competent catalyst for the ROP of *rac*-LA and ε-CL as well as their copolymerization via sequential addition of monomers, resulting in the formation of PCL-*b*-PLA diblock copolymer with controlled molecular weight distribution and narrow dispersity. The PLAs produced using this catalyst showed an isoselectivity of 0.85, which is the highest to date by a magnesium complex without using any external initiator. The polymers obtained were characterised by ^{1}H, ^{13}C, DOSY NMR, GPC, DSC, TGA, POM, and SEM. This work will encourage researchers to develop Mg complexes that could be utilised to synthesise biodegradable polymers with good selectivity.

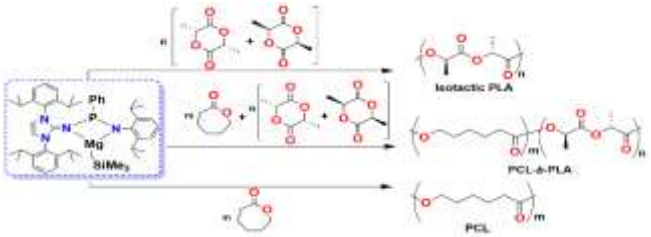


Figure 1 – Mg complex as a catalyst for ROP and ROCOP of cyclic esters in this work.

Keywords: Organomagnesium, ring-opening polymerisation, ring-opening copolymerisation, rac-LA and ε-CL.

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β-Ketimine-Supported novel Titanium Complex: A Versatile Catalyst for Ring-Opening Homo- and Copolymerization of Epoxides and Anhydride

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In this era of plastic pollution, aliphatic polyesters emerge as one of the most widely used synthetic polymers to replace the conventional polyolefins because of their biocompatible and biodegradable nature.[1] Ring opening copolymerization (ROCOP) of epoxides and anhydrides result in a bunch of different polyesters, and thus the limitation of less no of polymerizable cyclic esters can be avoided.[2] Here we synthesized a novel *β*-ketimine ligand supported titanium complex. The catalyst enabled the ring opening polymerization (ROP) of cyclohexene oxide (CHO) with controlled molecular weights and narrow polydispersity index (1.03-1.15) under solvent free condition and without external initiator. Furthermore, this catalyst showed superior activity towards ROCOP between CHO and glutaric anhydride (GA) with high monomer conversion at 2 h. It yielded well controlled random copolymer with different AB, ABB, BBB linkages corresponding to the ratio of CHO and GA.[3]

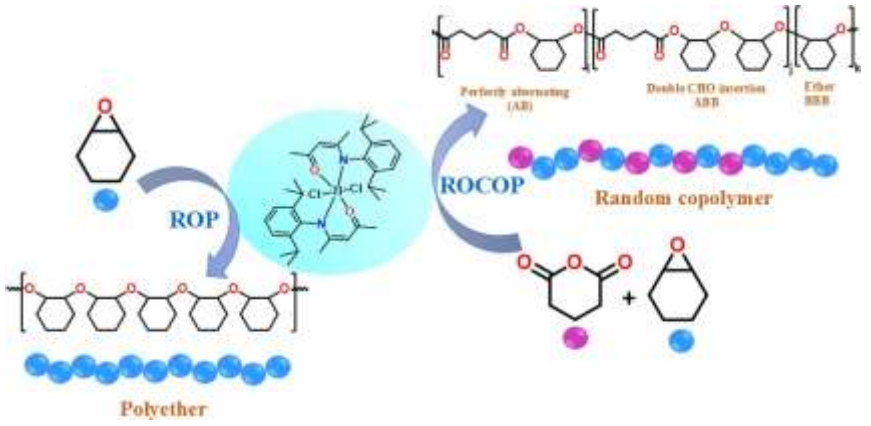


Figure 1 – ROP of CHO and ROCOP between CHO and GA using novel titanium complex.

Keywords: Earth abundant metal complex, biodegradable polyester.

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Ultrasmall Sulfur-Dots-Mediated Facile Photopolymerization for the Production of Smart Injectable Ink for 3D Printing Applications

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The pursuit of sustainable and metal-free methodologies for polymer synthesis has garnered growing interest due to the environmental and biomedical limitations associated with conventional catalysts.[1] In this work, we report a novel approach to photoinduced reversible deactivation radical polymerization (photoRDRP) mediated by ultrasmall sulfur dots (S-dots), a non-metallic, highly photostable, and water-dispersible quantum dot material.[2] This metal-free catalytic system successfully enabled the controlled polymerization of *N,N*-dimethylacrylamide (PDMA).

Utilizing PDMA as a macroinitiator, we synthesized well-defined double-hydrophilic block copolymers of PDMA-*b*-PHEAA effectively removed anionic dye contaminants such as Eosin B from water (Figure 1), showcasing their potential in environmental remediation. Further chemical modification of the PHEAA block with vinylbenzyl chloride yielded a new amphiphilic block copolymer, poly(*N, N*-dimethylacrylamide-*block*-poly(*N*-(2-((4-vinylbenzyl)oxy)ethyl)acrylamide) (PDMA-*b* -PVBEAA). Rheological studies confirmed that tuning the PEGDA content significantly affected the gel stiffness, and hydrogels with optimized compositions exhibited high storage moduli (~14 kPa). Morphological investigations via FESEM revealed well-defined, porous, and interconnected networks with narrow pore size distributions (~18 $\pm$ 5 nm), essential for high water uptake and structural fidelity. These injectable hydrogels were successfully applied in extrusion-based 3D printing to fabricate stable, patterned constructs with fine resolution. The hydrogel ink, composed of PDMA-*b*-PVBEAA and PEGDA, enabled precise deposition and printing of letters and free-standing structures without buckling or sagging, validating its potential as a writable gel-ink for advanced bio-fabrication. This study presents the first demonstration of S-dots as an efficient, sustainable alternative to metal-based photocatalysts in controlled radical polymerization.[3] The resulting functional block copolymers and printable hydrogels offer a versatile platform for applications in wastewater treatment, drug delivery, and particularly in customizable, biocompatible 3D-printed scaffolds for tissue engineering.

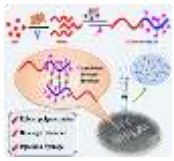


Figure 1. Schematic illustration of S-dots mediated photoRDRP toward the synthesis of 3D printable of PDMA-*b*-PVBEAA ink gel.

Keywords: 3D printing, block copolymers, injectable ink, photopolymerization, quantum dots.

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Development of Non-Toxic Biodegradable Color Masterbatch

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This study presents the preparation and characterization of biodegradable polymer composites based on polylactic acid (PLA) and polybutylene adipate terephthalate (PBAT), incorporating natural colorants to regulate color migration and assess their structural and biological performance. Natural dyes (0.25%) were incorporated individually into pure PLA and PBAT matrices, as well as Starch/PBAT blends (Starch 70– 80 wt%, PBAT 20–30 wt%). The resultant red, green, and blue blends were analyzed using energy-dispersive X-ray spectroscopy (EDS), which confirmed the presence of metallic constituents such as Al, Tl, and Fe. These elements were attributed to the natural colorants and polymerization catalysts. Biocompatibility was evaluated using BHK-21 cell viability assays(MTT assay), revealing high cell survivability across all colored composites, indicating negligible cytotoxicity and effective cell adhesion. The results confirm the non-toxic nature of PLA and PBAT blends containing these natural dyes, making them suitable for biomedical or food packaging applications. Mechanical testing using a universal testing machine (UTM) revealed that LP Green dye had the slightly less effect on tensile strength in PLA. This study underscores the importance of selecting polymers with low migration rates to ensure safer food packaging materials.[1-3].



Figure 1 – Development and characterization of non-toxic biodegradable color masterbatch.

Keywords: Non-toxic Color, Biodegradable Polymer, Sustainable Packaging, Color Migration, Color Masterbatch, Food Simulant.

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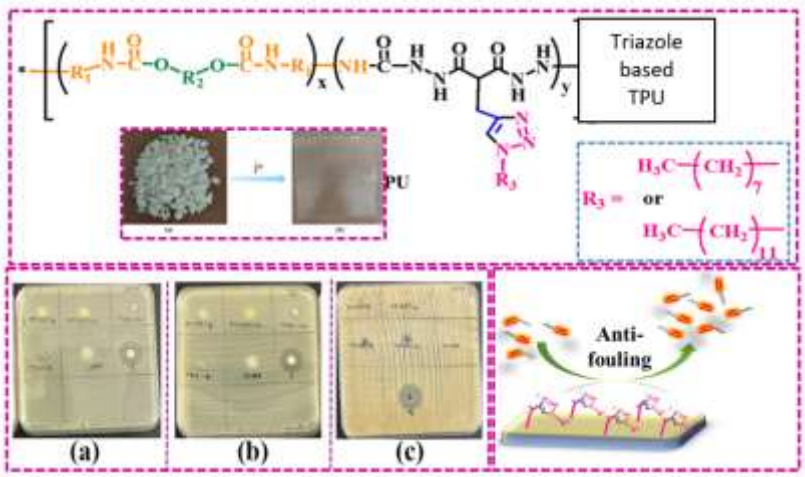
Thermoplastic Polyurethanes carrying Triazole moieties – studies on the properties and antimicrobial activity

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Thermoplastic polyurethanes (TPUs) stand out for their remarkable versatility, tunable properties, and broad applications in biomedical, automotive and industrial fields. However, polyurethanes (PUs), by their nature, tend to allow bacteria to adhere to their surfaces, which can lead to bacterial growth and biofilm formation. Because of this drawback, researchers have been working to modify PU materials in such a way that they inherently resist bacterial attachment and growth, rather than relying on external coatings or treatments. Covalent incorporation of quaternary ammonium compounds (QAC), pyridinium (Py) and triazole (Tz) moieties addressed the issues related to processability, long-term stability, mechanistic clarity, and translational feasibility.

This study reports the design and development of thermoplastic polyurethanes (TPUs) incorporating pendant 1,2,3-triazole (Tz) moieties. The triazole functionality was introduced via a Cu (II)-catalyzed azide-alkyne click chemistry approach which was converted into triazole based dihydrazide. TPUs were synthesised by reacting polyol, diisocyanate and the dihydrazide which were compression molded into films. Antimicrobial evaluations against *Escherichia coli* (Gram-negative), *Staphylococcus aureus* (Gram-positive), and *Candida albicans* (fungal strain) demonstrated that the triazole-functionalized TPUs effectively inhibited microbial growth and adhesion, indicating antifouling potential.



Keywords: Thermoplastic polyurethanes, antimicrobial, triazole, alkyne-azide click reaction

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Biodegradable Superabsorbant Polymers

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The present study introduces a simple and sustainable synthesis strategy for developing a **biodegradable, high-performance superabsorbent polymer (SAP)** based on **poly(vinyl alcohol-co-sodium acrylate)** [poly(VA-co-SA)]. The copolymer features an optimized crosslinked network that achieves a balance between **superior absorption under load** and **enhanced environmental degradability**. Biodegradability is imparted through the incorporation of **lactic acid–based crosslinkers** containing **polylactic acid (PLA) linkages**, which form a tunable three-dimensional hydrogel network. These multifunctional crosslinkers not only enable control over the crosslinking density and swelling behavior but also introduce **ester functionalities** that facilitate **controlled degradation** under composting or natural conditions, while preserving the **mechanical integrity** of the swollen gel.

Keywords: Superabsorbent polymer, Biodegradability, Poly(vinyl alcohol-co-sodium acrylate), Lactic acid based crosslinker, Sustainable materials

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Development of Biodegradable Pectin Films using Reject Water

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The increased environmental issues associated with petroleum-derived packaging materials have spurred interest in biopolymer alternatives. However, most biopolymer-based packaging relies on solvent casting, a resource-intensive approach using 80–97% water or organic solvents, raising issues of sustainability. This study investigates the potential of using reverse osmosis (RO) reject water as a solvent for pectin film formation, addressing both plastic pollution and RO reject water management challenges. The study leverages the potential of divalent cations in RO reject water to act as a crosslinker for pectin films [1]. The mechanical, barrier, optical properties, migration characteristics, biodegradability, phytotoxicity, and surface hydrophobicity of the films were assessed. Results show that films made with RO reject water demonstrated 40% increase in mechanical strength compared to control pectin film. The films also exhibited high germination rates of 151.1% in phytotoxicity tests. Migration testing in simulant D2 showed no disintegration, with migration rates <10 mg/dm², indicating suitability for oil-based or fatty food packaging. By recycling RO reject water, the strategy effectively tackles two urgent concerns: less dependence on fresh water for biopolymer processing and minimizing the environmental impact of disposal for RO reject water. The results illustrate a sustainable route for biopolymer packaging development with dual advantages of reducing plastic pollution and encouraging cost-effective water resource management.

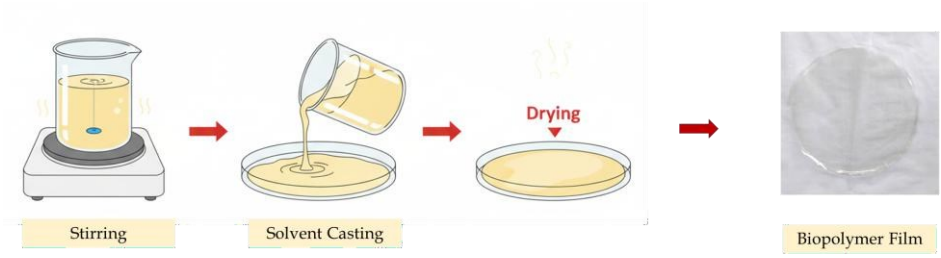


Figure 1 – Methodology of Biopolymer Film Preparation.

Keywords: Pectin, Divalent cations, RO Reject water, Biopolymer films, Biodegradable.

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Remediation of Organic Dyes Using Multifunctional Polysquaraines: Dual-Mode treatment for water purification

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The escalating threat of water pollution from synthetic dyes demands innovative and sustainable treatment technologies. In this study, two novel polysquaraines of type PSQ-X as a "molecularly-integrated single-component hybrid platform," were synthesized and characterized for advanced dye remediation.[1] PSQ-CH_2 polymer exhibited broad-spectrum adsorption-assisted catalytic degradation across multiple dye classes thus addressing the existing issue of secondary waste with real-world mixed effluents. On the other side, its oxygen analogue PSQ-O demonstrated dual functionality—adsorbing cationic dyes and degrading anionic dyes via catalytic ROS generation. This dual-mode remediation is the first report of its kind and shows an added layer sophistication that could be exploited as smart multifunctional polymeric platform that exhibits a charge-selective dye-remediation. These multifunctional polymers offer a scalable, energy-efficient approach to wastewater treatment, aligning with the principles of green chemistry and circular material design.

Keywords: Water purification, Dual mode dye-remediation, Polysquaraine, Adsorption, ROS generation.

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Controlling the Triboelectric Energy Harvesting Performance of Fibrous Materials by Polyvinylidene Fluoride Deposition

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Triboelectric energy harvesting has surfaced as a promising technique to transform mechanical motions into electricity. This technique has achieved the limelight of researchers with a view to alleviate the present issue of energy crisis. In this work, polyvinylidene fluoride (PVDF) layers were deposited onto needle punched nonwoven to produce triboelectric layers. Coated nonwovens, thus obtained, were undergone repeated contact-separation cycles with polyethylene terephthalate film to study the triboelectric energy harvesting performances of the nonwoven-based materials. Electrospinning technique was employed for the deposition of PVDF onto nonwoven. During the deposition, the electrospinning parameters were changed to achieve various morphological and structural properties of PVDF. Alternation in morphological property was found to change the roughness of the coated nonwoven. Moreover, change in structural conformation of PVDF altered the work function of the PVDF layer. Finally, an attempt was made to systematically analyze the effects of such morphological and structural changes on the triboelectric energy harvesting performance of coated nonwovens.

Keywords: triboelectric, energy harvesting, nonwoven, electrospinning.

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Electrospun nanocomposite of odd-numbered nylon for piezoelectric energy harvesting

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Mechanical energy harvesting using soft materials is receiving immense research interest due to its versatility and flexibility in applications, with an appreciable energy output. Smart energy harvesting techniques like piezoelectric energy harvesting has emerged as promising energy harvesting technologies. Flexible, light weight and sensitive soft materials like electrospun membranes have been extensively explored for piezoelectric energy harvesting. The latest discovery of piezoelectricity in odd-numbered nylons has escalated research in nylons as potential energy material. Nylon 11 has emerged as a piezoelectric polymer recently, among other odd-numbered nylons due to its facile processing techniques and lucrative properties. The loosely hydrogen-bonded δ phase of nylon 11 is preferred for piezoelectric applications due to its higher mechano-sensitivity compared to its other crystal phases. Apart from polymers, small molecules like glycine have reported appreciable piezoelectric coefficients. This study revolves around the influence of glycine on the piezoelectric phase of nylon 11[1]. Nylon 11/glycine electrospun membranes were prepared by varying different mass ratios of nylon 11 and glycine. It was observed that glycine positively influenced the δ phase content of nylon 11, while itself crystallized in its piezoelectric β form. The piezoelectric coefficient of optimized nylon 11/glycine nanofibers was 7.1 pm/V, which is significantly higher compared to 3.31 pm/V for pristine nylon 11. The enhanced piezoelectric property of the nanocomposite was further manifested in its improved electrical performance. The optimized nanocomposite produced an open-circuit voltage of 11.2 V in response to force of 1.3 N. The soft pliable material was explored as an effective biomechanical energy harvester. The minute deformation of the piezoelectric layer due to finger movement could generate few volts, indicating its competence for flexible wearable applications. Further, the developed soft material was tried for small electronic applications. It could successfully charge capacitors of different capacitance values in few minutes and light up LEDs to sufficient intensity. The development of such novel polymer nanocomposites with commendable piezoelectric properties is a step in the direction of creating bio-based sustainable energy sources, that could potentially contribute to mitigate the energy crisis.

Keywords: odd-numbered nylons, nylon 11, glycine, piezoelectricity, energy harvesting.

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Synergistic Integration of Sulfonated Polypyrrole Nanotubes and $Ti_3C_2T_x$ MXene for Enhanced Energy Storage in Supercapacitors

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Supercapacitors have attracted tremendous attention as next-generation energy storage devices owing to their high-power density, rapid charge–discharge capability, long cycle life, and environmental safety. However, achieving high energy density while maintaining good rate performance remains a major challenge. Conducting polymers, such as polypyrrole (PPy), possess excellent pseudocapacitive behavior but often suffer from poor structural stability and limited conductivity. To overcome these drawbacks, we have developed a series of sulfonated polypyrrole nanotube/$Ti_3C_2T_x$ MXene composites as efficient electrode materials for supercapacitor applications.The composites were synthesized by in situ oxidative polymerization using methyl orange as a soft template and metanilic acid as a sulfonating agent, with the amount of sulfonating agent systematically varied to optimize electrochemical performance. The incorporation of two-dimensional $Ti_3C_2T_x$ MXene, known for its metallic conductivity, large surface area, and tunable surface terminations, provided a robust conductive network for rapid electron transport and improved structural integrity. Meanwhile, the introduction of sulfonic groups into the PPy backbone enhanced hydrophilicity and facilitated ion diffusion, leading to improved redox activity and charge storage. Among the three prepared composites, the optimized sample exhibited an impressive specific capacitance of 795.87 F g^{-1} at a scan rate of 10 mV s^{-1} in a 1 M KOH electrolyte, using Ni foam as the current collector in a three-electrode configuration. Moreover, the sulfonated PPy alone demonstrated superior capacitance compared to the non-sulfonated form, confirming the beneficial role of sulfonation. The composite also delivered excellent energy and power densities, along with good cycling stability, demonstrating a strong synergistic interaction between MXene and sulfonated PPy. These results indicate that the designed hybrid material holds great promise as a high-performance electrode for advanced energy storage devices.

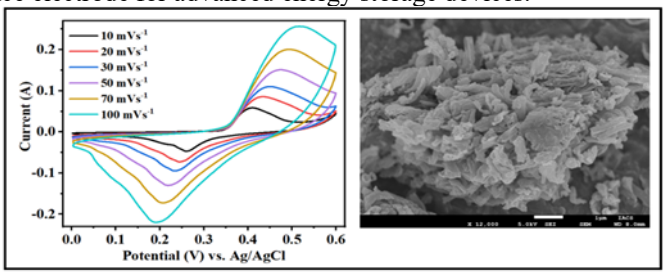


Figure 1 – Electrochemical analysis and SEM morphology of the sulfonated polypyrrole nanotube/Mxene composite.

Keywords: Sulfonated polypyrrole nanotube, $Ti_3C_2T_x$ MXene, Supercapacitor, Pseudocapacitance.

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Synergistic Impact of Catalytic Activity and Electric Field at Interface Layer Influencing Hydrogen Production in Bipolar Membrane Water Electrolyzer

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Effective design of bipolar membrane (BPM) interface plays a pivotal role in accelerating water dissociation (WD; $\boldsymbol{H_2O \rightarrow H^{++OH^-}}$) kinetics for its prospective applications in electrolyzers. Herein, we report role of metal-oxide nanoparticles (SnO_2/IrO_2) as interface layer (IL) catalysts to show high catalytic performance under strong electric field resulting reduced WD overpotential (η_{wd}). A stable poly(aryl piperidinium)-based anion exchange layer (AEL) is synthesized and characterized, to use in constructing the BPM using commercial Nafion as cation exchange layer (CEL). Loading optimization of synthesized SnO_2 (large surface hydroxyl groups, 1.04 mol per mole of SnO_2) indicates 50 μg cm^{-2} as IL catalyst in BPM. Subsequently, electronically conducting IrO_2 (5 wt % of SnO_2) was added to SnO_2 to find the effect in WD kinetics with enhanced electric field strength. The BPM with SnO_2 alone indicates η_{wd}, 169.91 mV (at current density, 350 mA cm^{-2}) in a single-cell DI water electrolyzer. While the addition of IrO_2 lowered the η_{wd} ~112.9 mV by 33.6 %, which is attributed to reduced overall electrolyzer cell voltage due to improvement in localized surface electric field. Evaluation of electric field over SnO_2 and IrO_2 nanoparticles using COMSOL Multiphysics confirmed surface localization of electric field, while the surface field strength of IrO_2 was greater than SnO_2. I-V characteristics of BPM with ~50 $\boldsymbol{\mu g cm^{-2}}$ SnO_2 as IL catalyst (BPM-Sn_{50}) showed superior performance with a total cell voltage of 2.20 V at current density of 500 $\boldsymbol{mA cm^{-2}}$. In contrast, BPM with no IL (BPM-0) attained 5.01 V with current density of 300 $\boldsymbol{mA cm^{-2}}$, whereas commercial FUMA BPM exhibited inferior performance with quite high potential ~5.00 V at a current density of 100 $\boldsymbol{mA cm^{-2}}$. BPM-Sn_{50}+$Ir_{5\%}$ (50 μg cm^{-2} SnO_2 with 5 wt% IrO_2 as IL) exhibited the highest hydrogen production rate among all tested BPMs (with and without IL), noted as ~0.21 L h^{-1} at a current density of 500 mA cm^{-2} for an effective membrane area of 1.0 cm^2 , in a single cell electrolyzer with circulating DI water at a temperature of 50 °C. This present investigation shows crucial properties of the IL catalyst required to develop high-performance BPMs for water electrolysis.

Keywords: Bipolar membrane, Water dissociation, Surface hydroxyl group, Electric field, Interface layer.

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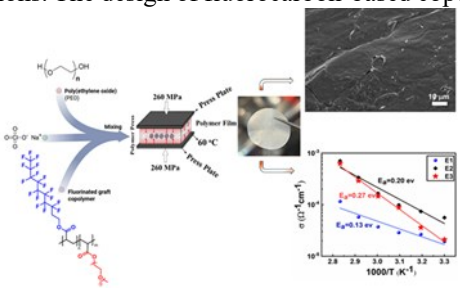
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Designing Fluorocarbon-Based Polymeric Electrolytes with High Cationic Transference Number for All-Solid-State Sodium-Ion Batteries

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Solid-state sodium-ion batteries have garnered a significant attention as a promising next-generation energy storage technology, offering a viable solution to the safety challenges associated with liquid electrolyte-based systems. [1] In this work, a solid-state polymeric electrolyte (SPE) comprising an amphiphilic graft copolymer containing perfluorocarbon (FC) and polyethylene oxide (PEO) segments, along with its PEO-based composite, is presented for fast cationic conducting all-solid-state sodium-ion batteries. [2] The fluorinated graft copolymer was observed to facilitate Na-ion transport, resulting in an enhanced ionic conductivity of ~8.4×10^{-5} S cm^{-1} at room temperature (30 °C), an order of magnitude higher than that of the pristine PEO electrolyte (5.3×10^{-6} S cm^{-1}). Furthermore, the copolymer exhibits robust mechanical properties when dispersed as a filler in a polymer-salt matrix and processed into an electrolyte membrane, while the PEO segments contribute to enhanced ionic conductivity. The incorporation of the perfluorocarbon segment also enhanced the cation transference number in the composite electrolyte to ~0.46 at 40 °C, one of the highest measured values for polymeric electrolyte systems based on PEO (t_{Na^+}0.26). Besides, the copolymer-PEO composite demonstrated improved thermal stability ($T_{d,5\%}$217 °C), over the copolymer alone ($T_{d,5\%}$133 °C), highlighting its suitability as a composite electrolyte for high-temperature applications. The design of fluorocarbon-based copolymer composite electrolytes with high sodium-ion transference number thus offers significant promise for the advancement of solid-state sodium-ion battery technologies.



Keywords: graft copolymer, ionic conductivity, transference number, composite electrolyte.

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Room Temperature Ferroelectricity in Self-Assembled Donor-Acceptor Systems

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Despite a long history and a growing interest in the field, only a handful of purely organic systems are known to exhibit ferroelectric (FE)-switching, that too mostly at sub-ambient temperatures. Among different building blocks, donor(D)-acceptor(A) charge-transfer (CT) complexes were reported to exhibit ferroelectricity.[1] To expand the scope of structural diversity, we have recently explored alternating supramolecular copolymer of a mono-amide functionalized naphthalene-diimide (NDI) acceptor and pyrene (Py) donor (Figure 1) for ferroelectric applications. NDI-Py (1:1) alternating supramolecular co-polymer [2] showed prominent rt ferroelectricity (T_c ~ 304 K) with a high saturation polarization (P_s ~ 3.3 μC.cm^{-2}),[3] that is comparable with the top values reported in the literature.[1] Interestingly neither NDI nor PY alone showed any signature of FE-switching, indicating essential role of the CT-interaction for making polarizable solid. We have further explored singe-component helical polyacetylene system (P1, Figure 1) with pendant ADA-type ambipolar chromophores.[4] Inspired by Parsoon's work on remarkable NLO property of dipolar chromophore-appended poly(isocyanide)s,[5] we envisioned that such dynamic helical polymer could be ideal for generating macro-dipole from the appended chromophores. Indeed P1, in a suitable solvent, showed clear signature of helical conformation, which produced a highly stable homochiral assembly with excellent ferroelectric hysteresis loop at rt, exhibiting saturation polarization (P_S) ~2 μC/cm^2 and remanent polarization (P_r) ~1.8 μC/cm^2 at a low coercive field (E_c) of 5.2 kV/cm, rarely reported before for any purely organic system. Same polymer lacking chiral side chain did not show such FE-switching. Highlight of these results will be presented.

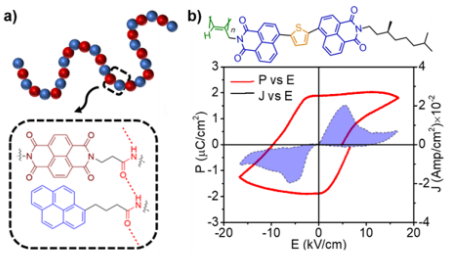


Figure 1. (a) Structure of NDI and Py and their alternating supramolecular copolymer. (b) Structure of chromophore-appended helical polymer (P1) and its FE-response.

Keywords: Donor-acceptor, charge transfer, supramolecular polymer, ferroelectricity.

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Comparative Study of SnO2 and TiO2 as Electron Transport Layers in CsPbBr3 Perovskite Solar Cells: Experimental and Simulation Approaches

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This work presents a combined experimental and simulation-based study to evaluate the role of electron transport layers (ETLs) in $CsPbBr_3$-based perovskite solar cells. $CsPbBr_3$ thin films are fabricated through a multi-step spin-coating method and characterized using XRD, HR-SEM, UV-Vis absorption, and infrared spectroscopy. The performance of TiO_2 and SnO_2 ETLs is systematically compared. Experimentally, the SnO_2-based device demonstrates a higher power conversion efficiency (PCE) of 4.97% (V_{OC} = 1.10 V, J_{SC} = 7.98 mA/cm^2, FF = 55.92%), outperforming the TiO_2-based device with a PCE of 3.86% (V_{OC} = 1.10 V, J_{SC} = 7.88 mA/cm^2, FF = 43.94%) [1]. Numerical simulations are further employed to examine the influence of absorber thickness, bulk and interfacial defect densities, series resistance, and operational temperature on device performance. The simulated results show that the SnO_2-based device with structure Glass/FTO/SnO_2/$CsPbBr_3$/Spiro-OMeTAD/Ag achieves a maximum PCE of 8.08% (Voc = 1.46 V, Jsc = 7.50 mA/cm^2, FF = 73.78%) as compare to the TiO_2-based with structure Glass/FTO/TiO_2/$CsPbBr_3$/Spiro-OMeTAD/Ag achieves PCE of 7.67% (Voc = 1.44 V, Jsc = 7.48 mA/cm^2, FF = 71.25%). These experimental and theoretical insights confirm that SnO_2 functions as a superior ETL compared to TiO_2, thereby enabling the development of efficient and stable $CsPbBr_3$ perovskite solar cells under ambient conditions [2].

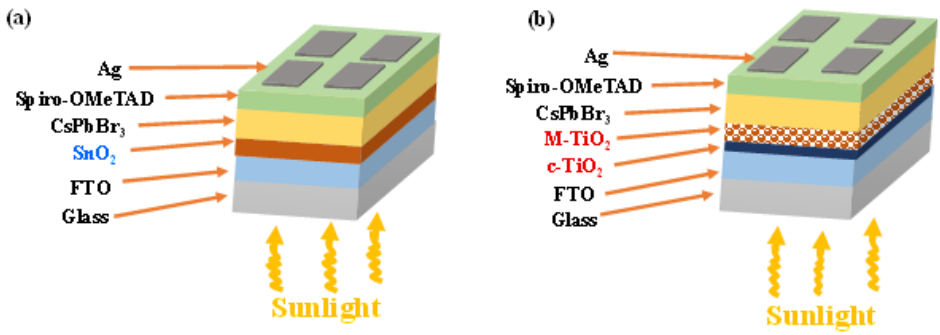


Figure. (a) & (b) is the animated structure of the SnO_2 and TiO_2-based device.

Keywords: perovskite solar cell; $CsPbBr_3$; HTL; ETL; numerical simulation.

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Functionalized Poly(vinylidene fluoride) for Piezoelectricm Nanogenerator: The Effect of Solvent and Unsaturation on Polar β-Phase

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Dehydrohalogenated poly (vinylidene fluoride) (D-PVDF) has been developed as a super piezoelectric materials and utilized as a novel nanogenerator for energy harvesting. Through structural and morphological alterations, the distinct impacts of alkali concentration and solvent dependency on the electroactive phase have been thoroughly investigated. A single-step process in a specific solvent produced about 85% of the piezoelectric β-phase, with a d33 of 11 $pC.N^{-1}$ unfilled polymer with no additional processing techniques. Using spectroscopic, thermal, and morphological studies, the cause of the electroactive phase—varying degrees of unsaturation—has been determined. This D-PVDF film is appropriate for device applications since it is tougher, ductile, and rigid by design. A very effective piezoelectric energy harvester has been created using this D-PVDF thin film. This device's ability to generate electrical power under mechanical stress over an extended period of time allows for accurate evaluation of its mechanical-to-electrical power conversion efficiency. With a maximum power density of 1218.8 μW/cm² under varying force and 289 μW/cm² under varied load resistance utilizing the finger tapping method, the manufactured device displays an extraordinarily high output voltage of 312 V. Its capacity to detect a human pulse is one of its primary features; it produces roughly 1.5 V at the wrist, 5 V at the left chest, and almost 0 V at the right chest. This manufactured device's remarkable charging capacity, which can reach about 4 V in just 50 s, is another noteworthy feature. Additionally, the underlying charge separation mechanism in the template system has been identified, providing insight into the remarkably high energy conversion efficiency of the device.[1]

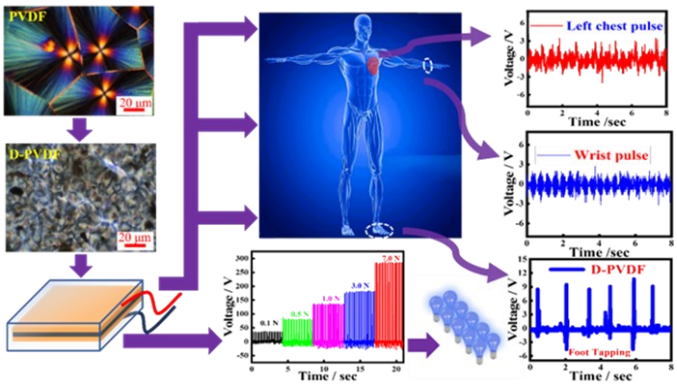


Figure 1: Flow diagram of piezoactive material preparation and its utilized application.

Keywords: Dehydrohalogenated PVDF, Energy harvesting, high power density, piezoelectric.

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Phase Study of MnO_2 and its application to Supercapacitor

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Energy storage is fundamentally required to bridge the temporal and spatial mismatch between energy generation and consumption. There are different types of energy storage devices like battery, capacitor, and Supercapacitor. Supercapacitors are gaining interest due to their high power density, but they show a lack of energy density[1]. To improve their energy density, extensive research is being conducted with various materials. In addition to this, we have reported a good and cost-effective transition metal oxide, manganese dioxide (MnO_2).MnO_2 exists in different polymorphic forms, among which four polymorphs □, □, □ and □ have been synthesize. Three polymorphs have been synthesised from hydrothermal conditions by varying the concentration of precursor and hydrothermal time, and one from the precipitation method. Furthermore, a time and concentration phase diagram has been prepared based on the time and concentration phase[2]. From the hydrothermal route, alpha polymorphs have been synthesized in just five minutes. As hydrothermal time increases alpha is getting converted into beta polymorph and as concentration increases alpha is getting converted into delta form. Alpha and delta polymorphs are obtained in just five minutes, and beta polymorphs are obtained in 100 hr. Further electrochemical characterization has been done for all materials, and it was found that the gamma form is giving the highest capacitance of 310 F/gm at 1mV/s.Furthur by using PVA/H_3PO_4 electrolyte device also been fabricated which is giving 1.8F/gm capacitance value at 1mV/s.

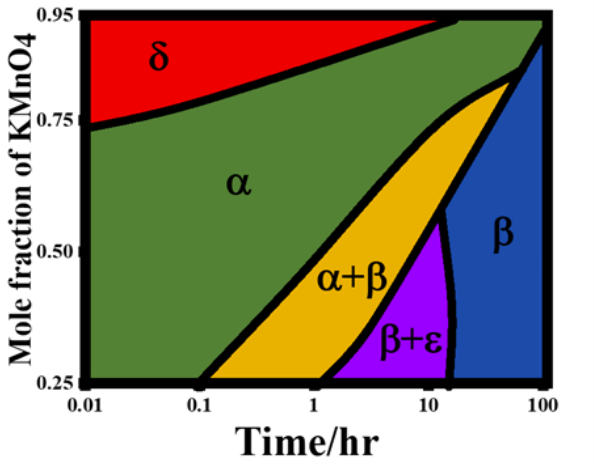


Fig. Phase Diagram of MnO2 polymorphs with respect to time and concentration of precursor.

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Plant-Based Polymer from *Moringa oleifera* for Sustainable Triboelectric Nanogenerator Applications

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The growing demand for sustainable polymeric materials in energy and electrical applications underscores the limitations of traditional synthetic elastomers in the design of triboelectric nanogenerators (TENGs) [1]. Researchers examined cellulose obtained from *Moringa oleifera* as a naturally occurring tribo-positive material for the development of robust triboelectric nanogenerators (TENGs). The cellulose obtained from agricultural waste was processed and incorporated into a TENG prototype, exhibiting a stable triboelectric response to mechanical stimuli such as pressure and sliding [2]. Initial assessments indicate that cellulose obtained from Moringa facilitates reliable energy generation, affirming its appropriateness for sustainable energy extraction. The incorporation of a conductive hydrogel matrix allows for screen printing of functional micro-patterns, thereby promoting adaptable and flexible device architectures [3]. This design indicates the potential application of cellulose-based hydrogels in future electronic skin (e-skin) systems [4]. The integration of mechanical sensing and energy generation would be facilitated. This study demonstrates that Moringa oleifera biomass may serve as a sustainable supply of polymers to further research on triboelectric nanogenerators and electronic skin within the domain of green energy materials [5].

Keywords: Triboelectric Nanogenerator, Moringa oleifera, Cellulose Hydrogel, E-skin, Sustainable Polymers.

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Sustainable Guar Gum Polymer for Green Energy and Intelligent Sensing with Machine Learning

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The growing demand for sustainable, flexible, and intelligent electronics has driven the emergence of natural polymers as wearable-sensing and energy-harvesting next-generation materials. In this work, we present a guar gum-based triboelectric nanogenerator (GG-TENG) that integrates green energy harvesting with smart sensing capabilities, making it a standalone wearable device for human–machine interfaces and health monitoring. Guar gum, being a biodegradable and renewable biopolymer, was fabricated into a thin-film device with the capacity to efficiently convert biomechanical energy from human motion into stable electrical outputs [1,2]. The remarkable environmental stability and ability of GG-TENG to operate at high temperatures such as 55 °C and relative humidity as high as 75% shows how much reliable it is for field use [3]. GG-TENG is a self-powered motion sensor which can detect biomechanical movements such as walking, bending, and stretching in addition to harvesting energy [4]. To accurately identify motion patterns, a hybrid machine learning structure comprising convolutional and recurrent neural networks was used to process the time-varying triboelectric signals [2]. This integration of artificial intelligence with a natural polymer sensor opens up a sustainable route towards intelligent and self-powered wearable devices. In addition, the GG-TENG has potential as a low-cost, biodegradable actuation device for medical monitoring and a dual humidity–temperature sensor for environmental applications [5]. The combination of renewable materials, energy harvesting and AI-sensing is the signature of guar gum's promise to be a universal platform for green and multifunctional electronics. The combination of smart energy and sensing technology with green materials by GG-TENG heralds next-generation self-powered wearable devices, adaptive healthcare sensors, and environmentally friendly electronic systems.

Keywords: Guar Gum-Based Triboelectric Nanogenerator, Self-Powered Wearable Sensor, Energy Harvesting, Machine learning, Healthcare sensors.

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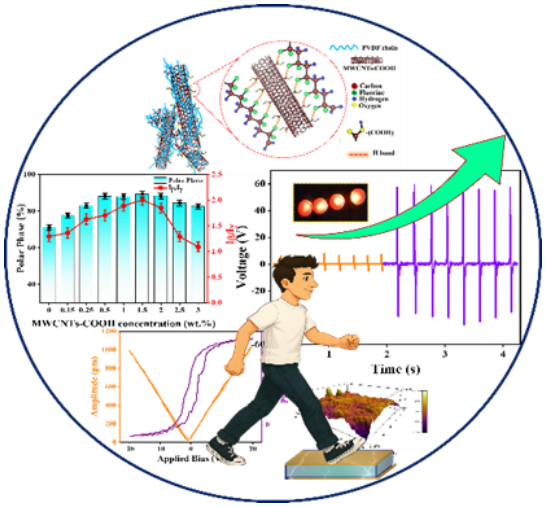
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Acid-Functionalized Multiwalled Carbon Nanotube Incorporated PVDF Nanocomposites as High-Performance Piezoelectric Nanogenerators for Bio-mechanical Motion Energy Harvesting

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Polymer based piezoelectric nanocomposites enhanced with nanofillers provide a scalable approach for efficient green energy harvesting. In this study, acid-functionalized multi-walled carbon nanotubes (MWCNTs-COOH) were incorporated into poly(vinylidene fluoride) (PVDF) matrix to evaluate their effect on the structural, morphological, and piezoelectric properties of PVDF/MWCNTs-COOH nanocomposites. The nanocomposites were prepared via melt-mixing followed by solution-casting, with MWCNTs-COOH content varied from 0 to 3 wt.%. MWCNTs-COOH acted as heterogeneous nucleating sites, facilitating the transformation of α-phase PVDF into polar (β/γ) crystalline polymorphs [1,2]. At 1.5 wt.% loading, the nanocomposite exhibited the highest polar phase fraction (~ 89%) due to uniform dispersion of MWCNTs-COOH, and achieved the maximum piezoelectric coefficient (d_{33}) of ~ 49.2 pm/V. The optimized piezoelectric nanogenerator (PENG P-1.5) fabricated with this composition delivered the highest performance, with a sensitivity of ~ 11.4 V/N, open-circuit voltage of ~ 59.2 V, and maximum power density of ~ 19.8 μW/cm². Energy harvesting from different bio-mechanical motions along with durability testing over three months demonstrated excellent stability, durability of the optimized PENG P-1.5. Importantly, the optimized device exhibits multifunctionality, operating effectively both as a sensor and as an energy harvester for diverse bio-mechanical motions [3].



Figures 1. Schematic depicting the interfacial interactions between MWCNTs-COOH and PVDF and variation of polar phase content leading to enhanced piezoelectric response and io-mechanical energy harvesting.

Keywords: acid functionalized MWCNTs, PVDF, melt-mixing, polar fraction, nanogenerator.

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***Corresponding Author:** arupranjan@iitb.ac.in

Transforming Energy Harvesting: Exfoliated MoS_2 Incorporated PVDF Nanocomposites with Extraordinary Piezoelectric and Piezocatalytic Power

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Piezocatalysis is a promising technique that utilizes piezoelectric materials to transform mechanical energy into chemical energy, enabling efficient chemical reactions such as pollutant degradation in water [1]. This approach offers sustainability, cost-effectiveness, and improved catalytic efficiency over conventional water remediation methods [2]. Piezoelectric materials uniquely convert mechanical stimuli like pressure, vibration, or strain, into electrical energy and vice-versa. Polymer-based composites are widely studied to improve piezoelectric performance for their structure and flexibility. Among these, poly(vinylidene fluoride) (PVDF) is favoured for energy harvesting applications due to its flexibility, facile processability, high dielectric breakdown strength, and piezoelectric properties [3]. This study demonstrates significantly improved piezoelectric properties in PVDF nanocomposites by incorporating molybdenum sulphide (MoS_2) exfoliated with mono-lithium adipate (Li-AA). The Li-AA enabled non-covalent exfoliation of MoS_2 into few-layered nanosheets, confirmed via Raman, XPS, and TEM analyses. The Li-AA exfoliated MoS_2 nanofillers were integrated into PVDF through melt-mixing and solution-casting, forming nanocomposite (PML) films. FTIR analysis revealed the PML (1:6) film had the highest polar phase content (~ 96%). PFM measurements showed a maximum d_{33} value of ~ 88 pm/V, due to increased polar phase content and better dipole alignment. The energy harvesting performance was validated with a voltage output of ~ 96 V, correlating with the higher electroactive phase. Furthermore, the nanocomposite efficiently degraded Rhodamine B with ~ 80.9% removal under ultra-sonic excitation. This highlights the role of Li-AA exfoliated MoS_2 in boosting piezoelectric and piezocatalytic capabilities of the nanocomposites, with promising applications in energy and environmental remediation.

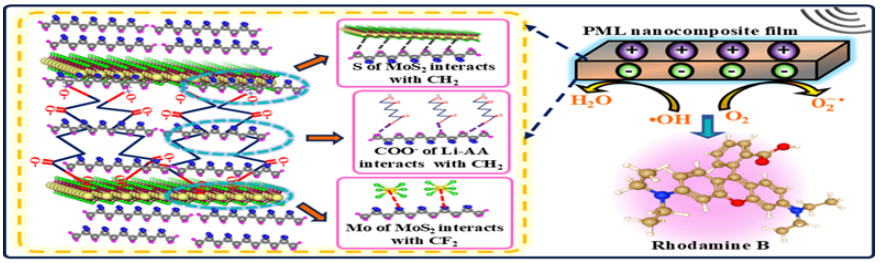


Figure 1 Schematic showing the interaction between MoS_2, Li-AA and PVDF chains and the mechanism of piezocatalytic degradation of Rhodamine B dye via the PML nanocomposite.

Keywords: PVDF, MoS_2, Piezoelectricity, Piezocatalysis, Dye degradation.

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Unlocking Sustainable Remediation and High-Performance Energy Harvesting via Hybrid 2D Nanomaterial Incorporated Poly(vinylidene fluoride) Nanocomposites

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Emerging contaminants (ECs), including pharmaceutical residues, industrial dyes, and endocrinedisrupting compounds, pose major risks to environmental and human health due to their persistence, toxicity, and bioaccumulation[1]. Developing sustainable solutions requires materials capable of coupling mechanical to chemical energy conversion for redox-driven degradation[1]. Here, we report a multifunctional poly(vinylidene difluoride) (PVDF)-based nanocomposite incorporating a hybrid nanofiller system of lithium adipate (Li-AA) modified MoS2 and BaTiO3, fabricated via synergistic melt-mixing and solution-casting. The 2D/0D filler design and effective exfoliation generated a highly electroactive microstructure, achieving ~95% β-phase fraction and a piezoelectric coefficient (d33) of 62.45 pm/V at 1 wt.% loading. Structural analysis (FTIR, Raman spectroscopy, Raman mapping) confirmed filler matrix interactions and phase evolution. The nanocomposite exhibited excellent piezoelectric energy harvesting, delivering an open-circuit voltage of 103 V, power density of ~95 μW/cm², and current density of ~1.7 μA/cm² under mechanical excitation. Guided by band theory and screening charge effects, the induced piezo-potential promoted electron transfer and ROS generation, enabling efficient piezocatalytic degradation. The films removed >90% of dyes and >80% of antibiotics under ultrasonic vibration. Degradation pathways were analyzed for ecological safety. This work establishes a structure property application link, positioning PVDF based hybrid nanocomposites as scalable platforms for energy harvesting and environmental remediation.

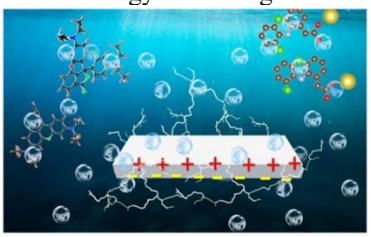


Figure 1: PVDF-hybrid 2D nanofiller composites enabling piezoelectric voltage generation and contaminant degradation.

Keywords: PVDF nanocomposite, piezocatalysis, emerging contaminants, energy harvesting, environmental remediation

References:

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Inversely Vulcanized Polymers with Flexible Oligoethylene Units as Active Cathode Materials for Lithium–Sulfur Batteries

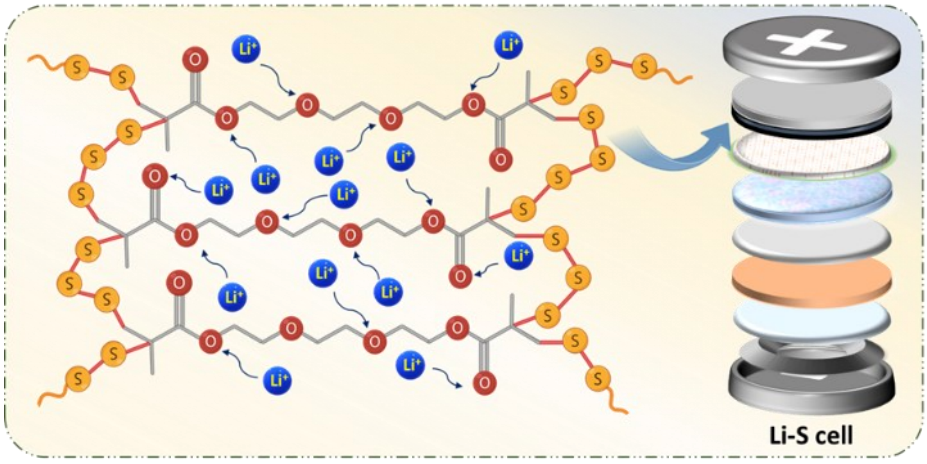
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Lithium-sulfur (Li-S) batteries are a promising next-generation energy storage technology due to sulfur's high theoretical capacity (1675 mAh·g^{-1}) and natural abundance. However, practical applications are hindered by the polysulfide shuttle effect and rapid capacity fade. In this work, polysulfide copolymers incorporating flexible oligoethylene segments were synthesized via catalytic inverse vulcanization of sulfur and triethyleneglycol dimethacrylate (TEGDMA), using zinc diethyldithiocarbamate as a catalyst. The successful copolymerization was confirmed through FT-IR, Raman, XPS, XRD, DSC, and TGA analyses. The resulting sulfur-rich copolymer was employed as a cathode active material in Li-S batteries. The electrode was fabricated using multi-walled carbon nanotubes (MWCNTs) as a porous conductive host to uniformly disperse the active material within its hierarchical structure. Morphological characterization via SEM and TEM revealed a homogeneous electrode composite, while EDAX analysis confirmed a sulfur-rich surface with evenly distributed oxygen. Electrochemical performance of the cathode was evaluated in a 2032-type coin cell configuration, demonstrating a high initial capacity of 1182.2 mAh·g^{-1} at 0.1C, indicating efficient active material utilization. The cathode also exhibited stable capacity retention over 100 cycles and superior rate capability compared to conventional sulfur-based cathodes.

ToC:



Keywords: Sulfur • Inverse vulcanization • Oligo-ethylene units • Cathode active material • Li-S batteries.

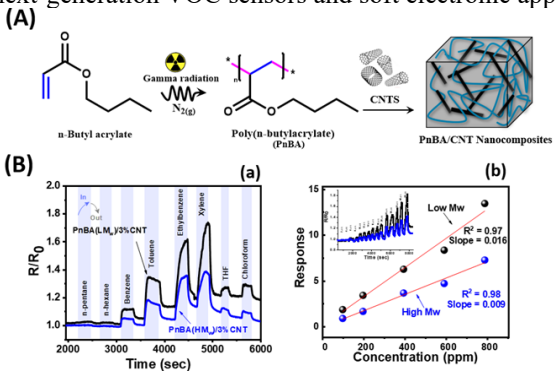
***Corresponding Author:** soumyadip.choudhury@rtc.iitkgp.ac.in

γ-Radiation Tailored Poly(n-butyl acrylate) based Chemiresistor for BTEX Detection

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Advanced polymer composites are increasingly replacing conventional mineral-based materials in industrial sectors such as aerospace, automotive, and biomedical engineering owing to their superior flexibility, lightweight nature, and tunable properties. Among them, radiation-processed elastomeric nanocomposites present a sustainable and versatile approach to achieving tailored functionalities. In this study, Poly(n-butyl acrylate) (PnBA) was synthesized via γ-irradiation using ^{60}Co γ-rays at different absorbed doses (60-700 Gy) to obtain polymers with controlled molecular weights. The synthesized polymers were characterized by ^{1}H NMR, vibrational spectroscopy, and GPC, which confirmed a linear correlation between molecular weight and absorbed dose. Conductive nanocomposites of PnBA with multiwalled carbon nanotubes (MWCNTs) were fabricated and evaluated as chemiresistive sensors for BTEX compounds. The PnBA/CNT composites demonstrated high selectivity toward xylene over ethylbenzene, with the lower molecular weight PnBA exhibiting higher sensitivity (0.016 ppm^{-1}) compared to the higher molecular weight counterpart (0.009 ppm^{-1}) at 3 wt% CNT loading. The improved sensitivity is attributed to increased surface area, enhanced VOC diffusion, and greater chain mobility in the lower molecular weight matrix, which facilitates rapid and efficient charge transfer [1,2]. These results highlight the potential of radiation-tailored PnBA/CNT nanocomposites as flexible and responsive materials for next-generation VOC sensors and soft electronic applications.



Figures 1 – PnBA/CNT-based chemiresistors. (A) Schematic of γ-radiation-induced synthesis of PnBA and fabrication of PnBA/CNT nanocomposites. (B) Chemiresistive performance of composites containing high- and low-molecular-weight PnBA with 3 wt% CNT loading.

Keywords: BTEX sensor; Radiation Polymerization; PnBA/CNT; Chemiresistor.

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Azobenzene Photoswitch in Asymmetric Polydiacetylenes dictates Molecular Ordering and Soft-Crystalline Transitions

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Stimuli-responsive chiral polydiacetylenes (PDAs) with an intrinsic photoswitch offer unique opportunities for modulating light-responsive chromogenesis and chiroptical properties through controlled E-Z photoisomerization. In this work, we present a series of asymmetric photopolymerizable diacetylene bisamides, in which variable alkyl chains bridge the PDA backbone with a chiral azobenzene unit. The designed monomers undergo topochemical polymerization in thin films to yield orange-colored PDAs characterized by extended fibrillar nanostructures, with longer alkyl spacers promoting pronounced axial or lateral growth upon thermal annealing due to enhanced polymer-domain ordering. The self-assembly of these PDAs reveals crystalline or soft-crystalline packing, determined by alkyl chain stacking, aromatic π–π interactions, and hydrogen bonding within the chiral framework. Such hierarchical packing strongly influences E-Z photoisomerization efficiencies, directly impacting the tuning of circular dichroism signals and the generation of anisotropic optical textures. Notably, PDAs with decyl chain spacers display prominent room-temperature soft-crystalline switching behavior, wherein E–Z photoisomerization triggers dynamic disassembly of one dimensional nanofibers. This order–disorder transition disrupts chiral packing and diminishes birefringent patterns, effectively coupling molecular switching to macroscopic optical responses. Importantly, reverse Z-E photoisomerization drives structural reordering, allowing full recovery of chiral domain organization, morphology, and optical anisotropy. This reversible behavior highlights the potential for designing adaptable PDA systems where supramolecular packing and chiroptical characteristics can be modulated on demand via light stimuli. The interplay between chiral group interactions, alkyl spacer length, and azobenzene switching provides a molecular-level handle to tailor PDA ordering and chromogenic functionality. Such tunable softcrystalline PDAs represent a promising platform for flexible, light-actuated chiroptical materials, with potential applications in solid-state sensing, optical data storage, and responsive photonic devices.

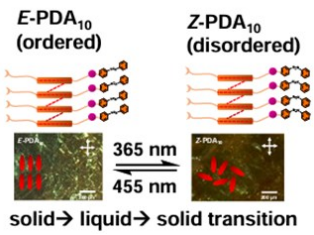


Figure 6. Polarized Optical Microscopy images of PDA2, PDA5 and PDA10before (A-C) and after (D-F) E-Z photoisomerization.

Keywords: photoswitch, polydiacetylene, topochemical polymerization, soft crystals.

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Conducting Polymer Electrodes in Energy Storage Devices

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The rapid transition toward sustainable and renewable energy systems requires storage technologies with higher efficiency, lower cost, and reduced environmental impact. Batteries, Supercapacitors, and Fuel Cells are being used nowadays for efficient renewable energy storage systems. These devices should be able to store a large amount of energy in a small, lightweight package and should be able to distribute that energy quickly for high-rate applications [1]. Conventional electrode materials, such as activated carbons and transition metal oxides, are commonly used but have certain drawbacks, such as low energy density, poor cycling stability, and reliance on non-sustainable resources. Conducting polymers (CPs) such as polypyrrole, polyaniline, and PEDOT, alternatives to conventional electrodes in supercapacitors and batteries, have emerged as active electrode materials for storing charge by rapid oxidation-reduction reaction [2]. Another important advantage of conducting polymers is molecular tunability. It can be designed to tailor porosity, morphology, and redox potential windows that improve energy storage performance by adjusting the polymer backbone, dopant species, and nano-structuring techniques [3]. Among these materials, Polypyrrole (PPy) can be used as a versatile electrode material due to its high electrical conductivity, ease of synthesis, and stability in the environment. It also exhibits good pseudocapacitive behavior, delivering high specific capacitance through rapid and reversible redox reactions [4]. It can be synthesized into various nanostructures such as nanofibers, nanotubes, and porous films, increasing the ion diffusion pathways and charge transport. Incorporating PPy with carbon nanomaterials or transition metal oxides as a composite material to improve the cyclic stability and energy density can be used for next-generation supercapacitors and batteries [5]. Recent developments in nano-structuring and composite formation have greatly improved the robustness and durability of CP-based electrodes, despite issues like volumetric swelling, limited long-term cycling stability, and possible degradation under harsh electrochemical environments.

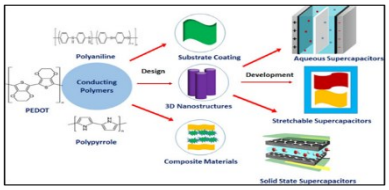


Figure 5- Role of Conducting Polymers in Various Energy Storage Application [4].

Keywords: Energy Storage Devices, Renewable Energy, Polypyrrole, Specific Capacitance, Reversible Redox Reactions.

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Understanding the Substituent Effect on MDMO-PPV: Molecular Electrostatic Potential and Density Functional Theory Investigation

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The electronic properties of MDMO-PPV and its derivatives were explored employing density functional theory (DFT), with a special reference to the effects of electron-withdrawing and electron-donating substituents, as well as the impact of truncating the side chains. The systematic introduction of various substituents on the polymer backbone, results the changes in the molecular orbital energies, charge distribution, and optical properties, which are crucial for their potential use in opto-electronic devices. Some results demonstrating the modulation of the bandgap, and the polymer aggregation propensity, dependence on the nature of the substituents. Also, truncating the side chains alters the conformational flexibility and intermolecular interactions, and affects the material's electronic behavior. This theoretical analysis provides insights into the design of high-performance conjugated polymers for applications in organic photovoltaics and light-emitting diodes.

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Porous Melamine Foam Composites with Carbon Nanoparticles for Enhanced Electromagnetic Interference Shielding

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In this study, lightweight melamine formaldehyde (MF) foams functionalized with conductive carbon nanofillers were fabricated via a simple dip-coating technique to evaluate their electromagnetic interference (EMI) shielding performance for protecting sensitive electronics. Multi-walled carbon nanotubes (MWCNTs) and graphene nanoplatelets (GNPs) were selected as fillers owing to their high electrical conductivity[1], large aspect ratio, and low density[2]. The nanofillers were uniformly dispersed in an MF resin at controlled loadings and subsequently deposited onto open-cell MF foams[3], yielding porous composite foams that maintained the lightweight architecture of the substrate while incorporating conductive networks. The composites were systematically characterized for microstructure, electrical conductivity, and shielding effectiveness across the X-band (8–12 GHz). Results revealed that both filler type and content strongly influenced the conductive pathways and corresponding shielding efficiency. The optimized MF/MWCNT composite with a thickness of 2.5 mm achieved a shielding effectiveness of 42 dB, corresponding to over 99.99% attenuation of incident radiation, demonstrating excellent performance despite the low filler loading and minimal thickness. Compared to conventional polymer composites, the dip-coating strategy provides a scalable and material saving processing technique, offering tunable performance by adjusting filler morphology, content, and coating uniformity. This work highlights the advantages of integrating lightweight foams with conductive carbon nanofillers, where the synergy between porosity and conductivity yields materials that are not only efficient in EMI shielding but also conformable, breathable, and lightweight. Overall, the developed MF/carbon nanofiller composites present strong potential for applications in electronics packaging, aerospace structures, and wearable devices where broad-band protection, flexibility, and reduced weight are critical requirements[4].

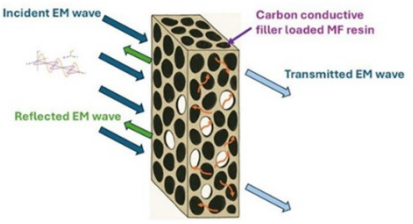


Figure 1: Schematic EMI shielding mechanism of MF foam composite loaded with carbon conductive fillers.

Keywords: Melamine formaldehyde, multi-walled carbon nanotubes, graphene nanoplatelets, composites, electromagnetic interference shielding

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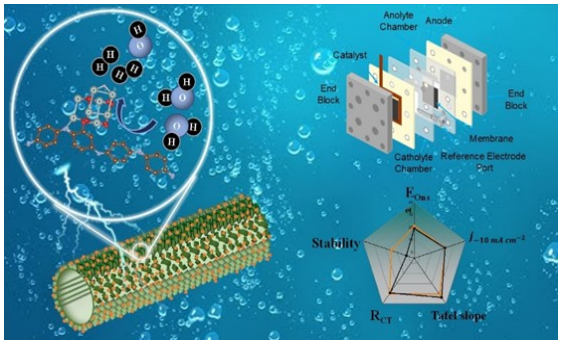
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Highly Stable Self-Supported PdO Nanostructure on the Conductive Polyaniline Nanotube Towards Extensive Electrochemical Hydrogen Evolution

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The quest for sufficiently stable and cost-effective electrocatalyst for the hydrogen evolution reaction (HER) has achieved tremendous interest to mitigate the global energy requirements. The modulation of electrocatalyst/electrolyte interaction is the pivotal step to generate the enhanced HER performances. Herein, it has been focused on the designing of a distinctly stable yet unexplored monodispersed polymer-metallic nanostructure as well as it aims to accelerate hydrogen production by tuning the active electronic environment of conducting polymer which provides site-selective platform for nanoparticles. Spatially uniformed as well as confined palladium oxide nanoparticles (PdO-NPs) are integrated selectively and uniformly on the surface of symmetrical organic acid doped polyaniline nanotubes (PANI_NTs) to generate a hybrid catalyst. Presence of repeating amine site provides the uniform platform for PdO adsorption and electronic structure modification of active Pd sites resulting enhanced electrocatalytic activity. PdO/PANI_NT-15 exhibits low overpotential of 67 mV to achieve 10 mA cm^{-2} current density and remarkable stability of 15 000 cycles of accelerated degradation test (ADT) with negligible depletion (1.36%) in comparison to commercially available Pd/C catalyst (76.09%). Chronoamperometric studies demonstrate its long-term durability (>100 h) with the higher current density utilising the custom-designed electrochemical flow cell. With the help of series of controlled experiments such as electrochemical studies, X-ray photoelectron spectroscopy, in-situ infrared spectroscopy, it has been inferred that the driving force behind the phenomenal performance of current system has been identified by mapping the active sites and charge transfer kinetics, reaction mechanisms which are further substantiated by first principle based DFT calculations.



Figures 1 – Schematic illustration of HER on PdO/PANI_NT with flow-cell set-up.

Keywords: Polyaniline nanotube, Conducting polymer, PdO, HER, Flow-cell.

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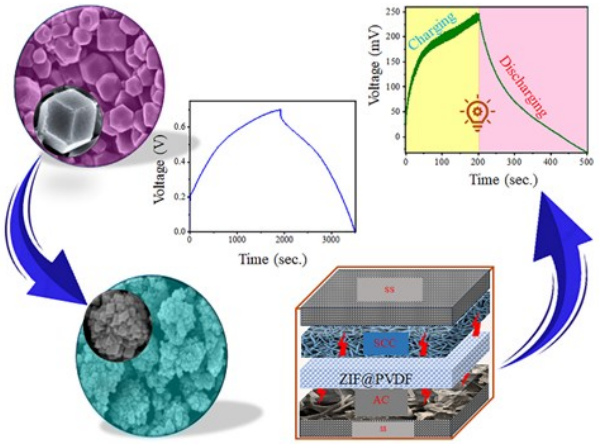
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High-Performance self-charging Supercapacitors Using MOF-derived Trimetallic SrCo/SrCu Layered Double Hydroxides

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Self-charging supercapacitors are attracting significant interest as they integrate energy harvesting and energy storage units in a single device, offering efficient solutions for powering portable electronics.[1-3] Here, in this work, we have fabricated a self-charging asymmetric supercapacitor cell (SCACC) device, using Sr-doped Co-Cu layered double hydroxide as the positive electrode and activated porous carbon as the negative electrode of the SCACC device, whereas ZIF-67 doped porous PVDF acts as the separator that generates an in-built piezoelectric field within the device to harvest energy. This SCACC device exhibits a specific capacitance of 172.9 Fg^{-1} with 100% specific capacitance retention (~ 20,000 cycles) and can also power up small electronic devices. The self-charging properties of the as-fabricated rectification-free SCACC device, under mechanical deformations, show that the device can be charged up to 246 mV. The self-charging behaviour of the as-fabricated device is explained through the piezo-electrochemical process. Hence, this study provides valuable insights into the field of self-charging energy storage and its practical applications.



Keywords: Self-charging, PVDF, Supercapacitor, Piezoelectric.

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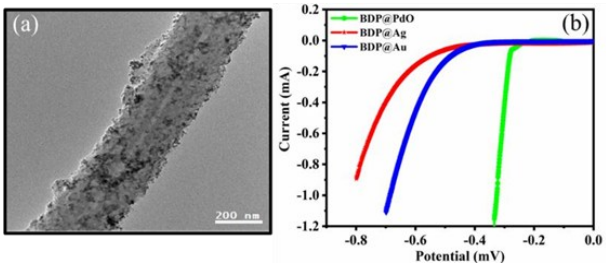
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Metal composite of Polyaniline nanotubes for HER: Metal Nanoparticle Catalysis and Thermodynamic–Kinetic Correlations

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The hydrogen evolution reaction (HER) is a pivotal half-reaction in electrochemical energy conversion, where the catalyst's electronic structure critically dictates activity. Based on the well-established volcano plot, platinum demonstrates the highest HER performance due to its optimal *d*-band energy center, which balances hydrogen adsorption and desorption kinetics. In contrast, other noble and transition metals, while HER-active, generally suffer from suboptimal hydrogen binding energies, resulting in higher kinetic barriers. In acidic electrolytes, proton adsorption at the catalyst interface followed by desorption constitutes the rate-determining step, thereby underscoring the importance of tailoring surface–adsorbate interactions. In this study, benzene tetracarboxylic acid doped polyaniline (BDP) has been employed as a conductive polymeric scaffold for the *in- situ* homogeneous synthesis of PdO, Au, and Ag nanoparticles. The BDP framework provides abundant coordination sites and electronic conductivity, facilitating uniform nanoparticle nucleation and intimate interfacial coupling with the polymer matrix. This strategy not only enables a one-pot synthetic route but also enhances charge transport properties during electrocatalysis. The HER activity of the resulting nanocomposites in acidic medium was systematically evaluated by linear sweep voltammetry (LSV), electrochemical impedance spectroscopy (EIS), and Tafel analyses. Onset potentials, charge-transfer resistances, and exchange current densities were quantified to establish a comparative kinetic profile. PdO, Au and Ag exhibit distinct variations in overpotential and interfacial resistance, highlighting differences in intrinsic catalytic activity and electron-transfer dynamics. The kinetic descriptors has been extracted from Tafel slopes provide a quantitative basis for assessing the activation barriers of the respective systems. This work demonstrates the utility of BDP as a multifunctional platform for controlled nanoparticle synthesis and HER catalysis. The comparative insights into PdO, Au, and Ag based electrocatalysts contribute to understanding their structure–activity correlations and may inform the rational design of alternative HER materials beyond Pt.



Figures 1. (a) FEG-TEM image of BDP@PdO, (b) Linear sweep voltammetry (LSV) curves of various metal nanoparticle embedded on Polyaniline matrix.

Keywords: Polyaniline, Nano particles, HER, Tafel plot, Overpotential.

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Nanostructured Polybenzoxazine Particles-Supported Ammonia Borane for Hydrogen Storage and Release

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Hydrogen, owing to its abundance, high energy density, and clean nature, is envisioned as a key driver of the future energy landscape, supporting the transition towards a "hydrogen economy"[1]. In this context, considerable research has focused on solid-state hydrogen storage using complex hydrides such as ammonia borane (AB), which shows strong potential to meet the U.S. Department of Energy (DOE) targets for on-board storage applications. AB has potential to release over 12 wt.% H_2 within the temperature range of 110–150 °C, the process is encountered by challenges such as thermolysis at elevated temperatures (> 110 °C), prolonged induction period with high activation energy (E_a ~180 kJ mol-1)2, particle aggregation, and the numerous byproducts generated during dehydrogenation, including borazine $(HNBH)_3$, diborane (B_2H_6), and ammonia (NH_3) that substantially reduce the hydrogen capacity. However, advancing solid-state hydrogen storage requires nanostructures that not only confine hydrides but also actively tune their decomposition pathways for controlled release[3,4]. Polymer nanostructures offer this advantage by providing tunable morphology, functional groups, and high surface area for strong hydride interactions. In this work, hydroxyl- and nitrile-functionalized polybenzoxazine (PBz) nanostructures were synthesized via a sol–gel method and employed as scaffolds for ammonia borane (AB) dehydrogenation[5]. Porosity was engineered using 1,3,5-trimethylbenzene as a dynamic porogen and mesoporous silica as a hard template, yielding hierarchical pore structures. Compared to neat AB, PBz-supported AB systems showed reduced dehydrogenation onset temperatures and lower activation energies (68.4 and 91.1 kJ mol^{-1}), indicating improved kinetics of hydrogen release. The PBz nanostructures retained structural stability and hydrogen release performance for up to three regeneration cycles. This study highlights the synergistic role of morphology control and interfacial chemistry in enhancing hydride destabilization, providing a versatile strategy for functional polymer-based hydrogen storage materials.

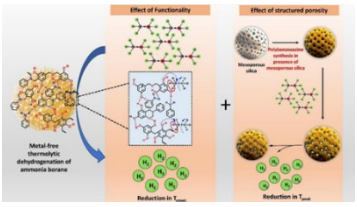


Figure 1. Thermolytic dehydrogenation of polybenzoxazine nanostructures-supported ammonia borane for enhanced hydrogen release.

Keywords: Polybenzoxazine; ammonia borane; functionality; nanoconfinement; hydrogen storage and release.

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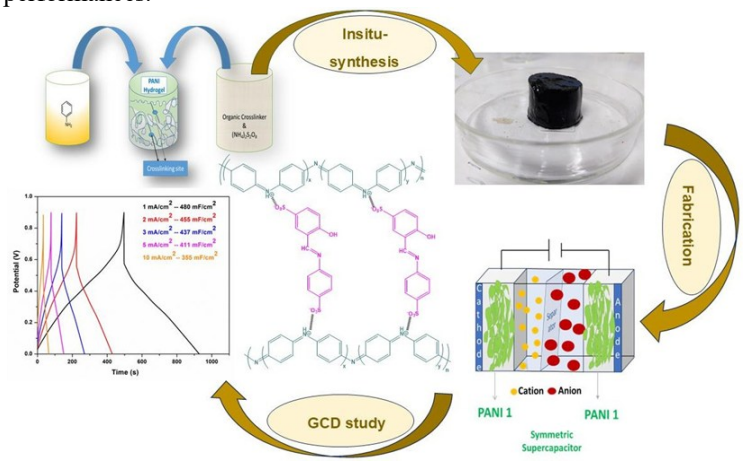
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Schiff base crosslinked Polyaniline Hydrogel via Insitu Polymerization as an outstanding electrode for Supercapacitor Applications

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Conductive polymer hydrogel draws significant research attention owing to its multipurpose applications in the electronics field. Conducting polymer-based hydrogel has recently been explored as an electrode material for energy storage applications. However, their widespread applications are often hindered by poor electronic conductivity and low cycling stability. Here, we develop a Schiff base bifunctional crosslinker crosslinked PANI hydrogel and investigate the electrochemical performance via a three-electrode and a two-electrode system. We have designed the crosslinker molecule so that it can induce inter-chain charge transfer from one PANI chain to another PANI chain and improve the electrochemical performance. This conductive PANI 1 has achieved a specific capacitance value of 1474 F g^{-1} at a scan rate of 5 mV s^{-1}, while its PANI 2 demonstrated 1259Fg^{-1} at the same scan rate. When evaluated using the galvanic charge-discharge method, the newly produced crosslinked PANI hydrogels exhibited a remarkable gravimetric capacitance of 912 F g^{-1} and 822 F g^{-1} at a current density of 1 A g^{-1} for PANI 1 and PANI 2, respectively. Both of them demonstrated excellent rate capability, maintaining at least 61% specific capacitance even at a high current density of 20 A g^{-1}. A symmetric supercapacitor fabricated by PANI 1 delivered an energy density of 54 µWh/cm^2 and a power density of 450 µW/cm^2 at 1 mA/cm^2 current density. After 5000 charge-discharge cycles, the device can retain 66% specific capacitance at 5 $mAcm^{-2}$. The counteranion effect is also studied here by choosing two different electrolytes. This research suggests that the conjugated crosslinker plays a significant role in the structural and electrochemical properties of the prepared PANI hydrogel, and it has improved the electrochemical performances.



Scheme 1: Schematic representation of PANI hydrogel synthesis and device fabrication.

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Title of Presentation: In-Situ Grown BTTh-Tz-COF Film for Dual-Responsive Vis-to-NIR Electrochromic and Bright-to-Quenched Electrofluorochromic Smart Windows

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Covalent organic frameworks (COFs) are promising materials owing to their high surface area, tunable porosity, mechanical robustness, and crystallinity, which make them suitable for electrochemical devices. Low bandgap COFs with π-conjugated donor–acceptor (D–A) architectures enable efficient electrochromism across the visible to near-infrared (NIR) region, offering high coloration efficiency and rapid switching. In this work, a novel COF, BTTh-Tz-COF, was synthesized via a one-pot condensation reaction and directly grown as an in-situ film on indium tin oxide (ITO) coated glass, overcoming limitations of ex-situ film formation. PXRD analysis confirmed high crystallinity with a sharp peak at 2θ = 4.32°, while BET measurements revealed a surface area of 819 m²/g with ~1.17 nm pore diameter. The electrochromic device (ECD) fabricated using BTTh-Tz-COF exhibited reversible multicolor switching from yellow to orange to reddish-brown under applied voltages of +1.7 V and +2.5 V. It demonstrated high coloration efficiencies of 738.4 cm²/C at 700 nm and 491.7 cm²/C at 1000 nm with fast switching (~5 s). The film blocked 67% solar irradiation with low energy demand, showing potential for smart window applications. Additionally, the device displayed reversible electrofluorochromism, where yellow fluorescence was quenched at +2.5 V and restored at –0.9 V, highlighting its durability and multifunctionality.

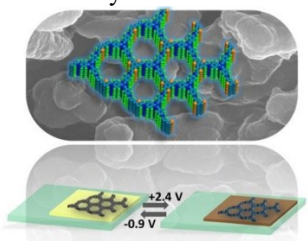


Table 1. Summary of EC parameters of BTTh-Tz COF-based ECD

Device	% ΔT	t_b/t_c (s/s)	Q_c/Q_d (mC/cm²)	CE (cm²/C)	$\eta_{photopic}$ (cm²/C)
BTTh-Tz-COF	68.7 at 700 nm & 43.3 at 1000 nm	4.3/4.9 at 700 nm & 5.5/5.7 at 1000 nm	0.97/0.78	768.4 at 700 nm & 491.7 at 1000 nm	656

Keywords: Covalent organic framework; Benzene-Trithiophene; Electrochromism; Heat-modulating smart window

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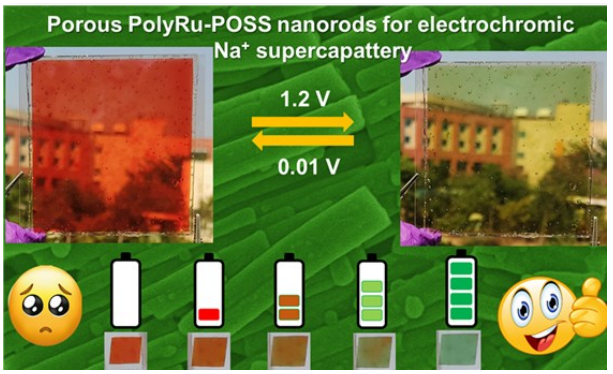
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Integration of POSS-Metallo-Polymers: Porous Nanorods Engineering for Bifunctional Electrochromic Sodium-Ion Supercapattery Towards Scalable Device

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The advancement of multifunctional nanostructures through dimensional nanoarchitectonics delivers a transformative pathway toward the next-generation electrochromic device with scalable applicability. On the other hand, the tailored integration of sodium-ion dynamics within the redox-active metallo-supramolecular polymer (MSP) reveals a new height for high-performance, durable, and scalable energy storage solutions. Here, we achieved a dimensional modification by incorporating cubic polyhedral oligomeric silsesquioxane nanocages into a Ru-containing PolyRu MSP matrix, transforming the aggregated structure into a homogeneous nanorod architecture. The incorporation also influenced the surface area, thermal stability, and electrochemical activity in PolyRu-POSS composites. The electrochemical studies revealed that the PolyRu-POSS50 composite, where 50% of chloride ions in PolyRu were exchanged with the POSS unit, exhibited the optimum electrochromic and highest energy storage capacity with the lowest charge transfer resistance. Moreover, the sodium ion integrated PolyRu-POSS50 and NiHCF-based hybrid EC energy storage device exhibited swift color change from red to green with a switching time of 1.1 s and 1.9 s for bleaching and coloration, respectively, a high coloration efficiency of 1032.52 cm^2C^{-1}, specific capacity of 17.45 mAh/g and an individual 10,000 electrochromic and charge-discharge cyclic stability. The successful development of a large-scale (100 cm^2) hybrid EC energy storage device underscores the practical viability of the materials for future commercial applications.



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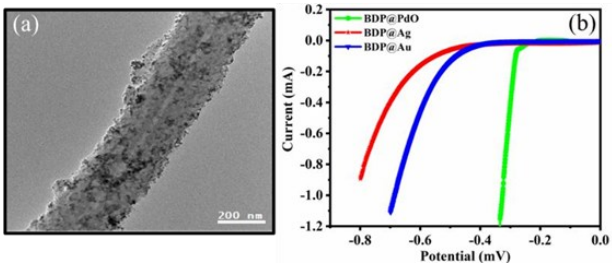
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Metal composite of Polyaniline nanotubes for HER: Metal Nanoparticle Catalysis and Thermodynamic–Kinetic Correlations

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The hydrogen evolution reaction (HER) is a pivotal half-reaction in electrochemical energy conversion, where the catalyst's electronic structure critically dictates activity. Based on the well-established volcano plot, platinum demonstrates the highest HER performance due to its optimal *d*-band energy center, which balances hydrogen adsorption and desorption kinetics. In contrast, other noble and transition metals, while HER-active, generally suffer from suboptimal hydrogen binding energies, resulting in higher kinetic barriers. In acidic electrolytes, proton adsorption at the catalyst interface followed by desorption constitutes the rate-determining step, thereby underscoring the importance of tailoring surface–adsorbate interactions. In this study, benzene tetracarboxylic acid doped polyaniline (BDP) has been employed as a conductive polymeric scaffold for the *in- situ* homogeneous synthesis of PdO, Au, and Ag nanoparticles. The BDP framework provides abundant coordination sites and electronic conductivity, facilitating uniform nanoparticle nucleation and intimate interfacial coupling with the polymer matrix. This strategy not only enables a one-pot synthetic route but also enhances charge transport properties during electrocatalysis. The HER activity of the resulting nanocomposites in acidic medium was systematically evaluated by linear sweep voltammetry (LSV), electrochemical impedance spectroscopy (EIS), and Tafel analyses. Onset potentials, charge-transfer resistances, and exchange current densities were quantified to establish a comparative kinetic profile. PdO, Au and Ag exhibit distinct variations in overpotential and interfacial resistance, highlighting differences in intrinsic catalytic activity and electron-transfer dynamics. The kinetic descriptors has been extracted from Tafel slopes provide a quantitative basis for assessing the activation barriers of the respective systems. This work demonstrates the utility of BDP as a multifunctional platform for controlled nanoparticle synthesis and HER catalysis. The comparative insights into PdO, Au, and Ag based electrocatalysts contribute to understanding their structure–activity correlations and may inform the rational design of alternative HER materials beyond Pt.



Figures 1. (a) FEG-TEM image of BDP@PdO, (b) Linear sweep voltammetry (LSV) curves of various metal nanoparticle embedded on Polyaniline matrix.

Keywords: Polyaniline, Nano particles, HER, Tafel plot, Overpotential

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Ultra-Light, High-Enthalpy Biopolymer Aerogel PCM Composites for Thermal Energy Storage

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Thermal energy storage systems utilizing phase change materials (PCMs) have emerged as critical technologies for sustainable energy management, yet conventional PCMs suffer from leakage issues and structural instability during phase transitions [1]. This work presents a novel approach for developing leak-proof, ultra-lightweight nanocellulose aerogel-PCM composites that address these fundamental challenges while achieving exceptional thermal energy storage performance. The developed system integrates organic PCMs within a three-dimensional nanocellulose fibrillar network through non-covalent physical interactions, creating form-stable composite materials that eliminate liquid leakage above the melting point. The nanocellulose aerogel scaffold, synthesized via freeze-drying methodology, provides a highly porous architecture with interconnected nanoscale channels that enable efficient PCM encapsulation while maintaining structural integrity. Differential scanning calorimetry analysis reveals an impressive latent heat storage capacity, indicating excellent thermal energy storage potential for passive cooling applications. The cellulosic matrix acts as an effective organogelator, enabling high PCM loading while ensuring complete absence of leakage [2]. Thermal cycling stability tests over 100 heating-cooling cycles show consistent latent heat storage performance without degradation, confirming the long-term reliability of the composite system. The aerogel-PCM composite exhibits superior thermal regulation capabilities compared to conventional insulation materials, effectively smoothing temperature fluctuations and reducing peak thermal loads. The sustainable nature of nanocellulose derived from renewable biomass resources, combined with the biodegradable and recyclable characteristics of the matrix material, makes this system environmentally advantageous for green building applications [3]. The developed lightweight, leak-proof nanocellulose aerogel-PCM composite presents significant potential for passive building cooling systems, offering a sustainable solution for thermal energy storage that combines high latent heat capacity, structural stability, and environmental compatibility in a single integrated material platform.



Figure 1. Illustration of charging and discharging of biopolymer aerogel due to climatic conditions.

Keywords: Phase change materials, Nanocellulose aerogel, Thermal energy storage, Leak-proof encapsulation, Lightweight composites.

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Influence of Amide and Imine Functional Groups on the Energy Storage Properties of Polymers

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In recent years, the renewable energy sources to generate the electricity and their storage attracted researchers' interest to tackle the environmental pollution problem. The batteries and supercapacitors are utilized as electrical energy storage devices. Supercapacitor (SC) displayed advantages over Li-ion batteries with respective to power conversion efficiency and cycling stability. The electrode materials are important to enhance the energy density and power density of the SCs. In this connection, redox-active polymer plays key role for the advancement of ten electrode materials in SC applications. The functionalization of polymers with specific chemical groups is a promising strategy for improving their performance in energy storage applications. Among these, amide (–CONH–) and imine (–C=N–) groups play distinct yet complementary roles. Amide groups contribute to high thermal stability, mechanical strength, and enhanced dielectric properties due to their strong polarity and hydrogen bonding capabilities. In contrast, imine groups, with their conjugated structures and redox-active behavior, facilitate improved electrical conductivity and reversible charge storage, making them suitable for use in supercapacitor and battery electrodes. This work explores the influence of these functional groups on polymer structure, charge transport, dielectric behavior, and electrochemical activity. A comparative analysis of recent advancements in amide- and imine-functionalized polymers highlights their potential in shaping next-generation materials for high-performance energy storage devices.



Figure 1. Applications of supercapacitors.

Keywords: Amide, Imine, Functionalized Polymers, Energy Storage, Supercapacitors.

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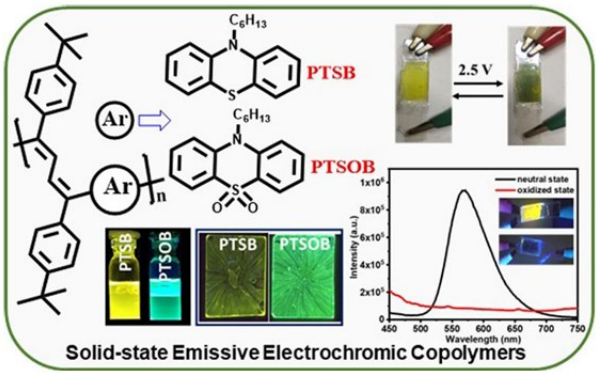
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Aryl-substituted buta-1,3-diene and Phenothiazine based Solid-state Emissive Copolymers: Synthesis, Characterization and Electrochromic Behaviors

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Two Phenothiazine containing aryl-substituted buta-1,3-diene based solid-state emissive copolymers1,2, PTSB and PTSOB have been designed and synthesized via Suzuki coupling reaction. The main difference of the two copolymers is in its sulfur oxidation state- neutral (zero oxidation state) in PTSB and sulfone (+2 oxidation state) in PTSOB. The effect of sulfur oxidation state on the optical and electrochemical properties have been studied. The higher emission maxima of PTSB compared to PTSOB have been supported by theoretical investigation using DFT. The experimentally obtained band gaps, PTSB (2.53 eV) < PTSOB (2.75 eV) is also in good agreement with the theoretically calculated values, PTSB (3.24 eV) <PTSOB (3.44 eV). Finally, PTSB have been fabricated as solid state electrochromic-electrofluorochromic3,4 device operating at a potential-windows of 0 to 2.5V. The device shows reversible color change from yellow to dark blue after applying voltage of 2.5V with coloration time (tc) = 3.0 s and bleaching time (tb) = 1.9 s with optical contrast (ΔT) of 35%. This behavior along with quenching of fluorescence color from yellow to dark by applying potential suggests its potentiality as electrochromic-electrofluorochromic polymer.



Keywords: Buta-1,3-diene, Phenothiazine, Solid-state emissive, Effect of sulfur oxidation, Electrochromic /Electrofluorochromic.

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Biobased Flame Retardant Solid Polymer Electrolyte For High Energy Li Ion Battery

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Here in we reported the synthesis of a novel biobased Polyurethane (VT-DOPO-PU) containing vanillin (natural renewable resource), flame retardant DOPO and a nitrogen rich moiety (Triazole) to achieve synergistic effect in order to design a flame retardant solid polymer electrolyte (FR-SPE) for high energy Li ion battery. The chemical structure of VT-DOPO-PU confirmed via FTIR, ^{1}H, ^{13}C, ^{31}P NMR and GPC. The polymer was found to be having porous structure and amorphous in nature from SEM and PXRD which is very favourable for the Li ion transference. It is thermally stable up to 250 ^{0}C tested by TGA. In order to study the flame retardant ability, the polymer was cured using diglycidyl ether of bispheol A (DGEBA) and 4,4-diaminodiphenyl methane (DDM). The limiting oxygen index (LOI) value raised from 22.8% of pure epoxy to 37.5% due to the addition of 10wt% VT-DOPO-PU and also passes vertical burning UL-94 V-0 rating respectively. The solid state polymer electrolyte (SPE) was designed by making a 9mm pellet using Lithium iron phosphate ($LiFePO_4$). The SPE with 40wt|% of $LiFePO_4$ achieves high conductivity of 2.7×10^{-4} S cm^{-1} at room temperature and 2.9×10^{-4} S cm^{-1} at 80 ^{0}C.

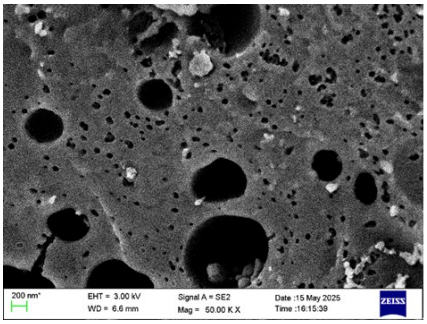


Fig.1: SEM image of VT-DOPO-PU**.**

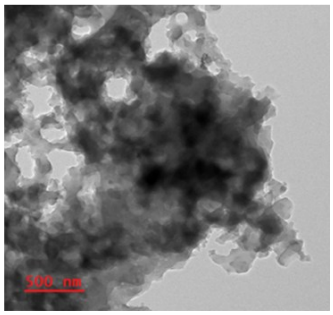


Fig.2: TEM image of VTDOPO-PU.

Keywords: Biobased, solid polymer electrolyte, flame retardant, conductivity.

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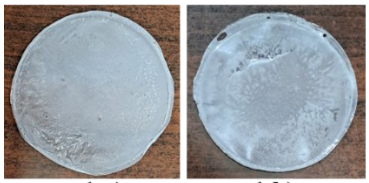
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Recent developments in Polysulfone based Anion Exchange Membranes for Water Electrolysis

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This paper shows recent developments in the Anion Exchange Membrane structures based on Polysulfone backbone for anion exchange membrane water electrolysis (AEMWE). Polysulfone (PSU) backbone provides promising thermal and mechanical strength, but due to its hydrophobic nature chemical functionalization is done to make it hydrophilic for transport of OH^- ions. Additional modifications are done to further enhance its ionic conductivity, chemical stability, durability and overall cell performance. This review paper provides modifications done in the recent timeline in synthesizing composite polysulfone membranes to improve its performance in AEWME for efficient generation of Green Hydrogen, and also provides future scope for the further improvement. Some of the highest reached ion conductivities are by integrating materials like Silica Nanoscale Ionic Materials (110 mS cm^{-1} at 80°C); Nanoclay Montmorillonite (47.3 mS cm^{-1} at 95°C); Graphene Composite Membranes (113.27 mS cm^{-1} at 80°C); Quaternized Carbon Dots (109.3 mS cm^{-1} at 80°C); TMPDA(Tetramerthyldiaminopropane) and PEG (104.67 mS cm^{-1} at 80°C); Triazatriannguleniumcations ($TATA^+$) (23.5 mS cm^{-1} at 90°C); BMP (4,4′- trimethylenebis(1-methyl-piperidine)) (53.7 mS cm^{-1} at 80°C); Nanocellulose (46.36 mS/cm at 80°C) and so on.



1.a) 1.b)



2

Fig. 1 − Pristine PSU membrane **a)** 2% PSU **b)** 10% PSU. **Fig. 2** – Different modifications of PSU.

Keywords: AEMWE, composite polysulfone, Green Hydrogen, chemical functionalization.

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Fine tuning of supercapacitor performance through compositional and morphological engineering of siloxene-polyaniline composites

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The increasing demand for sustainable energy solutions has driven the development of high-performance energy storage devices. Supercapacitors are promising candidates owing to their high power density, fast charge–discharge rates, and long cycle life, though their limited energy density remains a key challenge. The design of advanced electrode materials is therefore crucial to bridge this gap [1]. In this work, we report the fabrication of a siloxene–polyaniline (SPA) composite via an in-situ polymerization route as an efficient electrode material for supercapacitors. Siloxene, a silicon-based two-dimensional material containing Si_6 rings interconnected by Si–O–Si linkages, provides a stable matrix with surface functional groups that support electrochemical activity, while mitigating volumetric changes of polyaniline (PANI) during cycling. PANI, on the other hand, contributes high pseudo-capacitance and conductivity [2] but suffers from structural degradation upon repeated cycling. By integrating these complementary features, the SPA composite offers a synergistic improvement in performance. We systematically optimized the PANI content and morphology, transforming granular PANI into a nanofibrous (NF) structure, which effectively prevented the restacking of siloxene sheets and enhanced electrolyte ion diffusion. The SPA-NF composite exhibited a maximum specific capacitance of 785 F g^{-1} in a three-electrode configuration and an excellent cyclic stability with 94.6% retention after 10,000 cycles in 1 M H_2SO_4 electrolyte. Furthermore, a symmetric supercapacitor device assembled with the SPA-NF electrode delivered a high capacitance of 465 F g^{-1}, combining high energy density with robust stability. The practical applicability of the device was further demonstrated by successfully powering a red LED using two such symmetric cells connected in series. These results highlight the siloxene–PANI nanofiber composite as a strong candidate for next-generation supercapacitors, offering a simple and effective pathway to achieve both high energy density and durability.

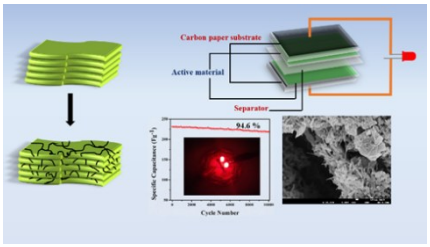


Figure 1– Schematic of siloxene–polyaniline composite fabrication, device setup, cycling stability, LED demonstration, and SEM morphology.

Keywords: Siloxene, Polyaniline, Nanocomposite, Symmetric supercapacitor, Energy storage.

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Single Sodium-Ion Conducting Sulfonated Polytriazole and Composite Electrolyte Membranes

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The growing demand for safer and more efficient battery electrolytes for next-generation secondary batteries, particularly sodium metal batteries (SMBs), has garnered significant attention worldwide. This focus stems from the potential of SMBs to address the increasing demand and cost of lithium metal batteries [1-3]. In line with this, the current study centres on the development of single sodium-ion conducting polymer electrolytes-cum-separators (SICPEs) and their composites, which exhibit enhanced thermal, mechanical, dimensional, and fire-retardant characteristics compared to traditional liquid electrolytes and the Celgard 2400 separators currently used in SMBs. The article focuses on the use of aromatic polytriazole-based PTSICPE-90 electrolytes and composites, which have been scarcely documented in the literature concerning their applications in SMBs. The investigation includes the design, synthesis, and characterisation of the sodium salt of sulfonated graphene oxide functionalized filler (Na-SGO) along with three distinct sets of SICPEs: PTSICPE-90, PTSICPE-90/PVDF-HFP, and PTSICPE-90/PVDF-HFP/X/X (where X represents 2, 4, 6, and 8 wt.% of Na-SGO loading). The developed Na-SGO filler demonstrated commendable Na-ion conductivities of 6.68×10^{-2} S/cm at 90 °C under 80% relative humidity (RH) and 11.91×10^{-2} S/cm in a solvated state. These values align well with the ionic conductivities observed in liquid electrolyte systems and are notably superior to those of other reported fillers for similar applications. Due to the high solvent absorption of SICPEs (70 wt.%), their wettability (22.2°), and significant porosity (58%), a decent Na-ion conductivities of 0.23×10^{-5} S/cm (non-solvated at 30 °C) and 1.17×10^{-5} S/cm (solvated at 40 °C) were observed. This positions them as a promising choice for electrolytic applications in SMBs. This study further clarifies how specific traits such as thermal, mechanical, dimensional, porosity, solvent uptake, wettability, phase-separated morphologies, and Na-ion conductivity can be modified through the structural engineering of SICPEs. The investigation emphasizes the essential advancements required in the design and optimization of SICPEs' performance to achieve safer and more efficient electrolytes for SMB applications.

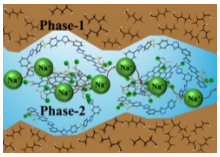


Figure 1: The structural engineering of the polymer electrolytes led to a self-assembled, phase-separated morphology, resulting in enhanced solvent absorption and wettability, which aids in improved sodium ion conductivity suitable for alkali metal battery applications.

Keywords: Hybrid polymer electrolytes, Single-sodium ion conducting polymer electrolytes, Phase separated morphology, Ion conducting channels, Sodium-ion conductivity.

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Sulfonated Fe-MOF–Polytriazole Hybrid Membranes with Enhanced Proton Conductivity: Structure–Property Relationships and Application Potential

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Proton exchange membranes (PEMs) are critical components in fuel cells and other electrochemical energy devices, where they function as ion-conducting barriers separating electrodes while facilitating proton transport. The performance of PEMs depends on achieving high proton conductivity, excellent oxidative stability, controlled water uptake, and robust mechanical properties.

In this work, we report the design and fabrication of advanced hybrid membranes based on sulfonated polytriazole (PTSF) matrices incorporating sulfonated iron-based metal–organic frameworks (Fe-MOFs). The Fe-MOF precursor was synthesized via solvothermal reaction of $FeCl_3 \cdot 6H_2O$ with 2-aminoterephthalic acid, forming Fe-MIL-53-NH_2, which was subsequently post-functionalized through ring-opening sulfonation using 1,3-propane sultone. This sulfonated Fe-MOF (Fe-S MOF) introduces abundant –SO_3H groups, enhancing hydrophilicity and providing potential proton-conducting sites.

The Fe-S MOF was homogeneously incorporated into the sulfonated polytriazole matrix via a solution blending method to prepare free-standing, flexible membranes with varying Fe-S MOF loadings (3–9 wt%). Detailed characterization confirmed successful synthesis and integration of the hybrid membranes. ATR-FTIR and XRD analyses verified chemical modifications, while SEM, AFM, and TEM imaging revealed uniform MOF dispersion and well-separated phase morphologies within the polymer matrix.

Thermal and mechanical testing demonstrated that the hybrid membranes retained high oxidative stability and good dimensional stability. The inclusion of sulfonated Fe-MOF improved water uptake (up to 38% at 80 °C) while maintaining controlled swelling ratios (7–15% at 80 °C). Importantly, proton conductivity was significantly enhanced, with maximum values reaching approximately 80 mS cm^{-1} at 80 °C, surpassing the pristine PTSF membrane. The improved proton transport can be attributed to the formation of interconnected ionic channels facilitated by the uniformly dispersed MOF nanoparticles and their hydrophilic domains.

These results demonstrate that the sulfonated Fe-MOF/PTS hybrid membranes offer an effective strategy for designing next-generation PEM materials. By balancing conductivity, stability, and processability, these materials show strong potential for use in fuel cells and other electrochemical devices requiring efficient ion-conducting membranes.

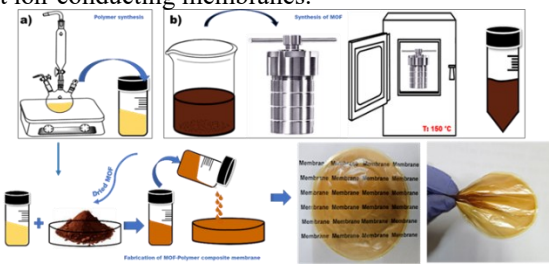


Figure 1 – Fabrication of MOF-Polymer composite membrane.

Keywords: Sulfonated polytriazole, Metal–organic framework, Proton exchange membrane, Hybrid composite, Fuel cell applications.

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Polybenzimidazole incorporated with Guinidinium salt for efficient proton exchange membrane

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High Temperature Proton exchange membrane fuel cells (HT-PEMFC) which uses Phosphoric acid (PA) doped membranes suffers from drawbacks such as PA leaching at higher temperature low PA doping ability low proton conductivity and reduced mechanical strength after doping in PA, in order to overcome this obstacles we have synthesised Pyridine, hydroxyl fuctionalised polybenzimidazole namely PhPyPBI, and Ph(OH)PyPBI by polycondensation reaction, after which both polymers were grafted with various percentages of N-alkylated tetramethyl guanidinium salt . The as prepared membranes owing to presence of guanidinium functionality in PBI membranes exhibited higher PA uptake and conductivity compared to pristane membranes, The optimal content of PhPyPBI 30% G exhibited shows PA uptake of 322.5 wt% and conductivity of 0.075 s cm-1 at temperature of 1600c which is ~7 times higher than pristine PhPyPBI membrane. Further, grafted membranes showed improved in thermal, oxidative, dimensional stability compared to pristine membranes

Keywords: phosphoric acid, grafting, guanidinium, polymers, membranes

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Flexible Biopolymer-based Triboelectret Nanogenerator: A New Class of Chemically Functionalized Cellulose made Emerging Self-powered Devices

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Self-powered energy harvesting technology have attracted significant attention for biomedical devices, smart sensors, wearable and implantable electronics.[1,2] In spite of the high efficiency and material versatility of triboelectric nanogenerators (TENGs), long term stability still persists due to poor charge retention abilities.[3,4] In this work, a new type of nanogenerator is introduced that simultaneously employs both triboelectric and electret features, named as triboelectret nanogenerator (E-TENG). Most importantly, both triboelectric active layers of E-TENG are composed of hydrophobic cellulosic materials that effectively overcoming the long-standing issue of charge annihilation in TENG. To tune, the surface potential, cellulose nanofibers have been functionalised for enabling tribo-negative surface and tribo-positive surface. The hydrophobic electret functionality, which enhances charge retention and long-term stability is achieved by forming a porous structure in the tribo-positive counterpart. The E-TENG outperforms traditional cellulose-based TENGs with a maximum power density of 6.8 W/m² with stable electrical output confirmed by long-term durability testing over 30 days. To demonstrate real-time self-powered sensing abilities, E-TENG is employed to monitor different biomechanical signals, including finger, wrist, and palm bending, muscle movements and tactile sensing. These findings pave the way for scalable, natural biopolymer-based electronics, enabling next-generation self-powered wearable devices, human-machine interfaces, and pervasive health care diagnostics.

Keywords: Cellulose, Triboelectret Nanogenerator, Energy Harvesting, Tactile Sensor, Wearable devices.

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BTCA-doped PANI/MoS_2 Ternary Nanocomposite: A Synergistic Hybrid for HighCapacitance and Thermally Stable Supercapacitor Electrodes

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The development of advanced electrode materials with high specific energy and robust cycling stability is critical for next-generation energy storage systems, including hybrid electric vehicles, solar energy harvesting, and grid-scale energy management. We report a novel ternary nanocomposite of Benzene Tetracarboxylic Acid (BTCA), Polyaniline (PANI), and exfoliated Molybdenum Disulfide (MoS_2), engineered to enhance supercapacitive performance. BTCA serves both as a dopant and structure-directing agent, facilitating the formation of uniform PANI nanorods and optimized at molar ratios of BTCA:aniline (1:4) and aniline:ammonium persulfate (1:1). The nanocomposite, synthesized via low-temperature in-situ polymerization, exhibits a hierarchical porous morphology, confirmed by FESEM and FETEM, with preserved MoS_2 crystallinity (SAED). FTIR and Raman spectroscopy reveal π-π and hydrogen bonding interactions, supporting efficient charge delocalization and ion transport. Thermogravimetric analysis confirms superior thermal stability, retaining ~90.7% mass at 800 °C. Electrochemical measurements show a specific capacitance of 420 F/g at 5 mV/s within a wide potential window (-0.4 V to 1 V), alongside excellent rate capability and low internal resistance (Rs ~0.67 Ω and Rct ~114.93 Ω). It shows an energy density (Eg) of 114.3 Wh/kg and power density (P) of 6858 W/kg. This ternary hybrid leverages the synergistic pseudocapacitive behavior of MoS2 and PANI, stabilized by BTCA's multifunctionality, making it a promising candidate for next-generation energy storage systems.

Keywords: Potential Window, Specific Capacitance, Energy Density, Power Density.

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Flexible Branched Poly (Aryl Piperidinium) Multication Anion Exchange Membrane for Enhanced Alkaline Water Electrolyzer Performance

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Anion exchange membrane water electrolyzers (AEMWEs) offer a promising, cost-effective alternative to proton exchange membrane water electrolyzers (PEMWEs) with favourable oxygen evolution reaction kinetics. However, their commercialization remains limited by poor chemical and mechanical stability of anion exchange membranes (AEMs) under highly alkaline conditions. We developed branched poly (aryl piperidinium) (PAP) polymers featuring strategically positioned piperidinium cations with crosslinker and side- chain twin quaternary ammonium groups to enhance alkaline stability and ion transport. The branched structure creates multiple cation sites that improve hydroxide conductivity while maintaining dimensional stability through enhanced microphase separation and interconnected hydrophilic domains. The developed AEM namely PTTPMPipCrQ2 and PTTPMPipQ3 achieved high hydroxide conductivities of 118 and 165.75 mS cm^{-1}, respectively, with excellent dimensional stability (swelling ratio <15%) at 80°C and strong mechanical properties (tensile stress: 117 MPa, strain: 27%). After 720 h in 5 M KOH at 80°C, PTTPMPipQ3 retained > 63% hydroxide conductivity. In alkaline water electrolysis tests using Ni-Co spinel anode and Pt/C cathode with 1 M KOH at 60°C, PTTPMPipCrQ2 and PTTPMPipQ3 delivered current densities of 0.6 and 0.85 A cm^{-2} at
2.2 V, respectively.

Keywords: Poly (Aryl)Piperidinium; Multication; Microphase separation; Hydroxide conductivity.

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Comparative Evaluation of Cobalt Pyrovanadate Stabilized Heterocyclic Azoles for Supercapacitor Application

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The wide spread catastrophe in energy due to the augmentation in global population fosters the necessity among scientists to develop remarkable energy storage materials. Also, the ascent in artificial intelligence (AI), specifically through energy intensive process in data centers, have aggravated carbon emission and energy use. Therefore, to overcome this prime challenge, it is pivotal to build up devices with high power density, good energy capacity and extended life span. Ascribing to these key features, supercapacitors have gained the attention of energy experts owing from its simplicity of use to its extended shelf life. In this study, initially, cobalt pyrovanadate ($Co_2V_2O_7$) was prepared through a facile technique. Then, $Co_2V_2O_7$ was subsequently doped on heterocyclic poly(azoles) viz., poly(pyrrole), poly(imidazole) and poly(1,2,4-triazole) respectively and thus produced corresponding electrode materials, viz., $Co_2V_2O_7$@PPy, $Co_2V_2O_7$@PIm and $Co_2V_2O_7$@PTa. The synthesized electrode materials were characterized through microscopic and spectroscopic techniques. Further, in order to examine the individual activity and superiority of the electrodes, a comparative electrochemical evaluation was performed using the prepared electrode materials with cyclic voltammetry (CV), galvanostatic charge - discharge (GCD) and Electrochemical Impedance spectroscopy (EIS) techniques. The obtained results suggested that the nitrogen rich polymer nanocomposite increased the specific capacitance, (Csp) with high charge transfer and low resistance. Therefore, the above assessment indicates that the constructed electrode offers high energy density and increased retention percentage which renders the capability of being employed as a unique electrode material for the designing of an efficient and reliable energy storage device which in turn be a piece of device for commercial application.

Keywords: Cobalt Vanadium Oxide, Heterocyclic Compounds, Specific Capacitance, Supercapacitors, Electrical properties.

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Synthesis of Conjugated Porous Organic Polymer for Electrocatalytic applications

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Nowadays, Researchers are focusing on replacing conventional energy with green renewable solar and wind energies. For the development of clean and sustainable fuel, hydrogen must be generated through metal-free electrocatalyst water splitting.[1,2] The development of efficient, cost-effective, metal-free catalysts for water electrolysis that can compete with platinum-based systems remains a persistent challenge. Conjugated polymer networks have emerged as promising candidates for the electrocatalytic hydrogen evolution reaction (HER).[3–5] Herein, we have designed two triazine-based conjugated polymer networks (TCPNs) - TCPN1 and TCPN2, by Suzuki-coupling of triazine acceptor core with phenyl (donor) or thiophene (donor) units, respectively, via a phenyl spacer. Experimentally, the pristine TCPN1, with a larger bandgap, exhibited a high overpotential (535 mV) to achieve a current density of 10 mA cm^{-2}, while TCPN2, with a narrower bandgap, exhibited slightly improved performance (457 mV). Strikingly, electrochemical activation of both catalysts via prolonged negative potential polarization (-0.40 V vs RHE) for 5 h dramatically enhanced their HER activity (Figure 1). Post-activation, TCPN2 achieved 10 mA cm^{-2} at a significantly reduced overpotential of 211 mV, outperforming TCPN1 (293 mV) and many reported metal-free catalysts. This work underscores the critical role of electrochemical activation in optimizing HER activity and establishes a robust framework for designing metal-free electrocatalysts. The insights presented here advance the rational design of efficient and sustainable alternatives to noble metal-based electrocatalysts.

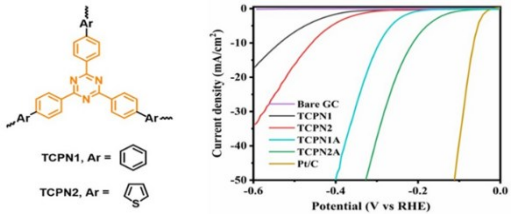


Figure 1. Chemical structure of TCPN1 and TCPN2 and its Linear sweep Voltammetry plot.

Keywords: Triazine, Hydrogen Evolution reaction, Conjugated polymer network, Electrocatalysis, Over potential.

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Conjugated Polymer Network Based on Fluorene-Triazine and their Side-Chain Polarity Dependent Photoluminescence and Deep Blue Electroluminescence

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The development of solution-processable deep blue electroluminescent materials has gained significant research attention.[1] Higher dimensionality in conjugated systems can result in distinct solid-state superstructures that may exhibit unique optical and electronic properties.[2] Conjugated polymer networks which belong to higher dimensional polymer with extended π-conjugation and permanent micropores have garnered significant research attention owing to their high chemical stability, adjustable pore structures, high specific surface areas, and reversible redox chemistry. These materials show a broad range of applications in numerous fields such as catalysis,[3] energy storage, sensing,[4]optoelectronics, and many more. Here, we have demonstrated the synthesis of two conjugated polymer networks made of triazine and fluorene that are solution-processable, highly fluorescent, and have a wide band gap (Figure 1a). To examine the impact of side-chain polarity on the fluorescence and electroluminescence characteristics of the polymer, two distinct side-chain alkyls, and ethylene glycol are introduced to the polymer backbone. The polymer network with an alkyl side chain displays a deep-blue luminescence whereas its ethylene glycol counterpart exhibits green. When used as an emissive layer after doping in TCTA matrix in electroluminescence device, both the polymer shows deep blue electroluminescence (Figure 1b). The maximum quantum efficiency (EQE) of OLEDs based on FCPN2 (ethylene glycol chain) is 2.7%, which is significantly higher than the 0.5% displayed by FCPN1 (alkyls side chain). These findings underscore the potential of sidechain polarity to tune the fluorescence and improve electroluminescence performance of conjugated polymer based blue OLED devices.

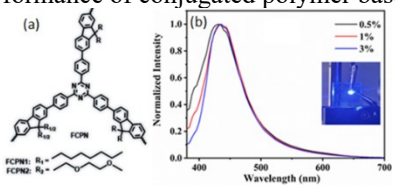


Figure 1. (a) chemical structure of FCPN1 and FCPN2 (b) electroluminescence spectra of OLED devices from FCPN2 doped in different amounts in host TCTA matrix (inset light emission from a device).

Keywords: Conjugated Polymer, Organic light emitting diode, External Quantum Efficiency, Fluorescence, Electroluminescence.

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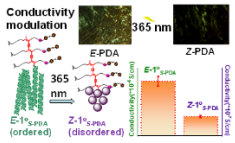
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Controlling Topochemistry in Chiral Diacetylenes toward Tunable Molecular Packing and Conductivity

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Chiral π-conjugated polymers are particularly promising for chiral catalysis and plasmonics due to their tunable optoelectronic properties modulated through hierarchical molecular chirality and visualized via chiral spectroscopy. In that regard, polydiacetylenes are a fascinating class of conjugated polymers known for sensing and recognition owing to their stimuli-responsive ene-yne backbone. Inducing chirality in polydiacetylenes provides an additional handle for tunable chiroptical behavior in thin-films and solutions.[1-3] Although polydiacetylene research is mainly focused on colorimetric sensing, chirality-driven structure-property co-relation in has not been explored in the same toward flexible optoelectronics. Herein, we explore the role of chiral group interactions and molecular packing in photoswitchable diacetylenes to control the ordering in polydiacetylene monolayers via azobenzene photoisomerization. While exploring a series of asymmetric phenylalanine anchored azo-diacetylenes with odd/even alkyl spacers and terminal carboxylic acids, we found that varying the hard-soft segment ratio impacts polymerization kinetics, azobenzene photoisomerization, chiroptics and solid-state monolayer ordering. Stronger molecular interactions in the chiral system renders better packing efficiency in polymer monolayers and record higher photoisomerization percentages as compared to the achiral analogs. We also observe tunable circular dichroism signatures wherein generation of ordered polydiacetylene domains furnishes bright birefringent patterns under cross-polarizers. Interestingly, *E-Z* photoisomerization leads to the weakening of the self-assembly, triggering a dynamic order-disorder transition in the polymer solution. Such transition is exploited to establish control over conductivity where *E*-azobenzene functionalized polydiacetylenes exhibits ≈3 fold higher values than the corresponding *Z* analogs in solution-processed thin-films having potential utility towards energy storage applications.[4]Topochemical polymerization in PDA self-assembly exhibiting tunable molecular ordering upon reversible *E-Z* azobenzene photoisomerization to alter birefringence pattern and conductivity.



Keywords: birefringence, photoisomerization, polydiacetylene, topochemical polymerization, azobenzene.

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Multi Emissive Graphene Oxide Quantum Dots Showing Remarkable pH Responsive Long Wavelength Emission

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This work describes the preparation of graphene oxide quantum dots (GOQDs) through oxidative cutting of graphene oxide nanosheets under controlled conditions [1-3]. The resulting GOQD solution exhibited a strong dependence of its optical emission on pH. At acidic to near-neutral pH, the emission maxima appeared in the green to yellow region, originating from hydrogen-bond-driven J-type aggregates that acted as the emissive species. In contrast, at highly alkaline pH (12.8), the solution displayed an intense orange–red emission with a relatively high photoluminescence quantum yield of about 30%. This unusual [4-5] emission under basic conditions was attributed to aggregation of negatively charged GOQD particles, most likely stabilized through donor–acceptor interactions among their surface functional groups At pH 12.8, the orange–red fluorescence was strongly quenched when electrolytes were introduced, as cations triggered aggregation of the emissive assemblies, thereby suppressing their light emission. Additionally, GOQDs obtained at pH 2 (with a photoluminescence quantum yield of 37.8%) were incorporated into a polyvinyl alcohol (PVA) matrix and coated on a 390 nm UV chip. The resulting PVA–GOQD film produced bright, nearly pure white light, characterized by CIE chromaticity coordinates of (0.336, 0.388), a color rendering index (CRI) of 85, and a correlated color temperature (CCT) of 5160 K.
Moreover, the PVA–GOQD films and gels exhibited excellent stability when exposed to both sunlight and UV radiation, underscoring their potential as robust photoemissive materials for use in light-emitting diode (LED) applications.

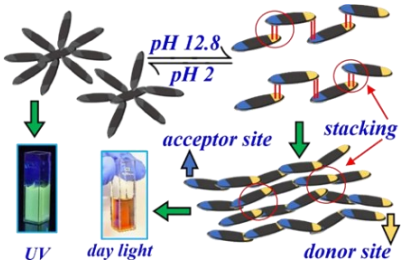


Figure 1: Different supramolecular interactions led GOQD aggregates at different pH values governing the emission characteristics of dilute aqueous GOQD solution.

Keywords: Graphen Oxide Quantum Dots, J-type aggregates, Donar-Acceptor interaction, Photoluminescence.

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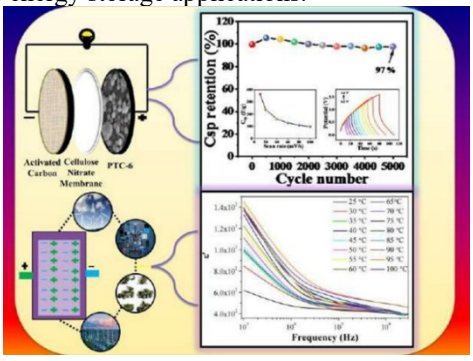
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Effect of clay on TiO_2 embedded PMMA nanocomposite for high-performance energy storage application

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The cost effectiveness, easy preparation, low toxic, thermally and chemically stable nanomaterials are utterly utilized in the field of solar cell, energy storage devices, power electronics and sensing purpose devices [1]. The polymer based metal oxide (MO) related nanocomposites are broadly used for electronic, catalytic, storage and sensing purpose [2]. The present work deals with the dielectric and electrochemical properties of PMMA/TiO2 and PMMA/TiO2@Clay nanocomposite prepared via a simple sol-gel method followed by ultrasonication. With pore diameters of 16.657 Å, ternary nanocomposites have an increased specific surface area of 28.88 m2/g. The significant dielectric properties are observed for PMMA/TiO2 and PMMA/TiO2@Clay nanocomposite with the highest dielectric constant □□ of 3.66 × 103 and 1.45 × 103 and maximum dielectric loss □□□ of 1.7 and 1.9 at 1 kHz respectively. The PMMA/TiO2 nanocomposite exhibits the highest □ac conductivity of 1.29 × 10-4 S/m and 6.85 × 10-2 S/m, whereas the PMMA/TiO2@Clay nanocomposite demonstrates the highest □ac conductivity of 1.47 × 10-4 S/m and 1.84 × 10-2 S/m at 1 kHz and 3 MHz, respectively. The manufactured device's highest specific capacitance was 364.13 F/g, which corresponds to an energy density of 129.26 Wh/kg and a power density of 2913.04 W/kg. Even after 5000 CV cycles, a 97% capacitance retention was reported in the cyclic stability. The present work proves its virtue and competency towards superior energy storage applications.



Keywords: Nanocomposite, Dielectric constant, Energy density, Conductivity, Storage.

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Solid Composite Electrolyte with Functional Covalent Organic Framework Filler for High Performance Lithium Batteries

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Solid polymer electrolytes (SPEs) offer a promising pathway toward safer and more stable all-solid-state lithium batteries. Among them, poly(ethylene oxide) (PEO)-based electrolytes are widely studied due to their strong lithium salt solvation ability. However, their high crystallinity and poor mechanical suppression of dendrites limit their practical applicability. In this work, a porous anthraquinone-based covalent organic framework (COF) was synthesized and incorporated into a PEO matrix to form a composite solid electrolyte. The COF, synthesized through Schiff-base condensation between 2,6-diaminoanthraquinone (DAAQ) and 1,3,5-triformylphloroglucinol (TFP), exhibited a porous structure beneficial for lithium- ion transport. Integration of the COF into PEO led to a significant enhancement in both ionic conductivity (7.3×10^{-4} S cm^{-1} at 60 °C) and lithium-ion transference number (0.44), owing to the suppressed crystallinity of PEO and improved ion transport pathways. The composite SPE demonstrated excellent electrochemical stability in Li/$LiFePO_4$ coin cells, achieving a capacity of 83.6 mAh g^{-1} after 250 cycles at 1C. These results highlight the potential of COF/PEO composite electrolytes for next-generation solid-state lithium batteries.

Keywords: Solid Polymer Electrolyte (SPE), Covalent Organic Framework, LiF-rich SEI, Dendrite Suppression, Flexible Lithium Battery.

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Supramolecular Self-Assembled, Conductive, Mechanically Flexible MXene Cross-Linked Polypyrrole Hydrogel for Wearable Energy Storage Applications

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Wearable supercapacitors, an emerging integrable power source for conformable bioelectronics, offer high power density, flexibility, and longevity. Conducting polymer hydrogels (CPHs) meet these unique demands by integrating electronic conductivity and mechanical flexibility, making them promising electrode materials for seamless interfacing with biological tissues. Nevertheless, most pristine CPHs are brittle and crack under deformation, sacrificing device performance while risking unwanted immunological responses. Herein, a conductive, biocompatible, and mechanically robust 3D polypyrrole (PPy)-$Ti_3C_2T_x$ hydrogel (PMCH) is reported to overcome these challenges in wearable supercapacitors. A multi-step ultra-fast reaction mechanism has been proposed, wherein $Ti_3C_2T_x$ nanosheets (NSs) effectively cross-link PPy chains, endowing structural elasticity to the PMCH. The hierarchical, water-saturated mesopores guaranteed an ion-rich hydrophilic environment, boosting access to redox-active sites. Varied hydrogels with impressive mechanical properties and high water content, mimicking human tissues, were constructed. Among the formulations, the PMCH-3 (only 33.33 wt.% $Ti_3C_2T_x$) delivered a striking specific capacitance of 368.3 F g^{-1} and cyclic stability of 85.5% after 12500 cycles at a realistic current density of 20 A g^{-1}. The solution-processable hydrogel synthesis technique supported remarkable electrode mass loadings of 30 mg cm^{-2}, with the 10 mg cm^{-2} variant delivering an excellent areal capacitance of 2.2 F cm^{-2}. As a definitive proof-of-concept, an electronic glove designed with all-gel solid-state supercapacitor devices operating at commercial loadings successfully powered a red LED under bending while retaining 92.1% of its capacitance across 1000 bending cycles, showcasing excellent wearability. The all-gel solid-state device delivered a state-of-the-art energy density of 49.8 **μ**Wh cm^{-2} and a peak power density of 8000 **μ**W cm^{-2}, while concomitantly maintaining a stable performance across a temperature range of 10 - 50 °C, meeting the rigorous demands of next-generation wearable electronics.

Keywords: wearable supercapacitors, PPy-$Ti_3C_2T_x$ hydrogel, self-assembly, ultra-fast gelation.

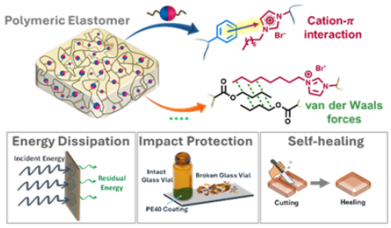
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Cation-π Reinforced Terpolymer with Tunable Energy Dissipation, Self-Healing, and High-Impact Resilience

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Recent developments in polymer-based materials for energy absorption and impact protection utilize reversible dynamic covalent and non-covalent bonding mechanisms. Notable examples include supramolecular elastomers, vitrimers, polymer fluid gels, and polyurethane nanocomposites offering properties like stretchability, damping, and self-healing.[1] [2] However, challenges remain, such as limited healing efficiency, complex synthesis, and trade-offs between integrated functionalities. Thus, developing multifunctional materials that enable simple, one-step synthesis while combining energy dissipation, impact protection, and Self-healing is an emerging but still relatively untapped area for future protective technologies. In this work[3] we report a multifunctional terpolymer, poly(butyl acrylate-*random*-styrene-*random*-octyl vinyl imidazolium bromide) [poly(BA-*r*-St-*r*-[octVIm]Br)], designed to achieve superior impact resilience through cation-π interactions between styrene and imidazolium units. This interaction enhances mechanical toughness and introduces strain-dependent viscoelastic behavior-exhibiting rigidity under low strain rates and transitioning to a soft, dissipative state under high strain. Rheological analysis shows a high storage modulus and a tunable damping factor (tanδ = 1.06-1.35), ensuring efficient energy dissipation. Thermal analysis confirms good stability, with degradation starting at ~280 ºC, making it suitable for high-temperature use. Notably, the material exhibits intrinsic self-healing capabilities, restoring mechanical integrity after damage. Its strong adhesive properties further expand its usability in diverse environments. The combination of structural robustness, adaptability, and functional recovery positions this terpolymer as a promising candidate for applications such as protective coatings, energy-damping systems, and structural reinforcements. This study demonstrates a versatile strategy for designing next-generation impact-resistant and self-repairing polymeric materials.



TOC Graphic

Keywords: impact-resistant polymer, cation-π interaction, self-healing material, energy dissipation, viscoelasticity.

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High-performance flexible supercapacitor based on PEDOT:PSS wrapped delaminated Ti3C2Tx composite: Experimental and DFT validation

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This innovative research introduces PEDOT:PSS (PP)/delaminated MXene (d-Ti3C2Tx) binary nanocomposites as exceptional electrode materials for flexible supercapacitors. Using a cost-effective approach that combines mixed acid etching with DMSO intercalation, we optimized PP/d-Ti3C2Tx at a 1:2 weight ratio (P1M2), achieving remarkable electrochemical performance [1]. The P1M2 electrode exhibited an outstanding specific capacitance of 718.67 F g-1 at 3.5 A g-1 in 1M H2SO4 electrolyte. First-principles DFT calculations revealed a unique charge storage mechanism in which PEDOT chains wrapped d-Ti3C2Tx nanosheets through electrostatic interactions, while PSS chains created interconnected electron-rich pathways between nanosheets (Figure 1). The P1M2-rGO asymmetric solid-state supercapacitor displayed superior stability, with ~89% capacitance retention after 5000 cycles, delivering specific energy (power) values ranging from 35.29 Wh kg-1 (240 W kg-1) to 26.22 Wh kg-1 (1200 W kg-1). The computationally obtained absorption spectra aligned remarkably well with experimental results, validating our proposed composite morphology. Notably, the device maintained its performance integrity during mechanical deformation and successfully powered a red LED for approximately 2 min, establishing this technology as highly promising for next-generation flexible and wearable electronic applications that require both high energy density and mechanical durability.

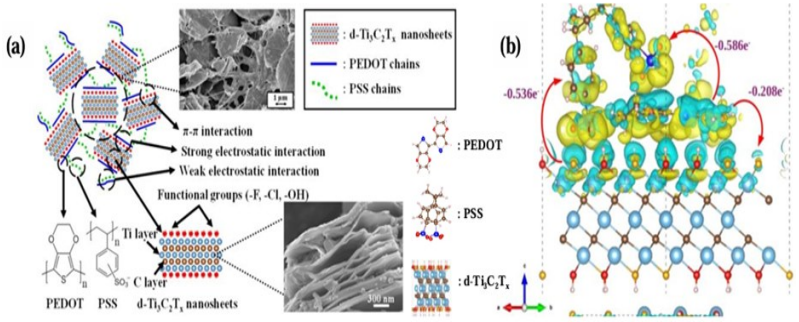


Figure 1. (a) Schematic of P1M2 composite with probable interaction, (b) Charge transfer in P1M2 system.

Keywords: Ti3C2Tx-MXene, PEDOT:PSS, Flexible supercapacitor, DFT, Charge transfer

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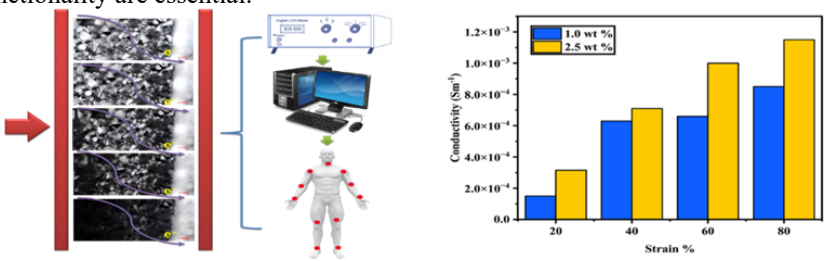
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Nanofiller-infused flexible PU foam for sensor application

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In this study, traditional flexible polyurethane (PU) foam was modified into a conductive composite foam using a simple and effective method. Graphene nanoplatelets (GNPs) were incorporated into the PU matrix to form continuous conductive pathways within the foam structure (Chen et al. 2023). This modification aimed to utilize the foam's potential as a dielectric material that responds to mechanical stress, particularly for sensing applications (Liu et al. 2017; Tolvanen et al. 2016). The dielectric properties of the modified foam, including capacitance and electrical conductivity, were examined under various levels of compressive strain and testing frequencies. The presence of graphene facilitated improved charge transport. A mini compression setup was used to apply controlled stress to the foam, while a digital multimeter recorded the resulting changes in electrical properties. Tests were carried out under both low and high-frequency conditions, and the foam was subjected to strains up to 80%. The results showed a strong correlation between applied stress, frequency, and dielectric response. At higher strains, the formation of conductive networks within the foam became more prominent. The morphology and mechanical properties of the foam were also examined. The nanofillers were uniformly distributed, making it suitable for wearable sensing applications. This study demonstrates the potential of conductive PU foam as a stress-sensitive material that can be used in applications such as wearable sensors for real-time body movement monitoring. The combination of low weight, flexibility, and electrical responsiveness makes it a practical choice for use in emerging technologies where adaptability and multifunctionality are essential.



Keywords: Polyurethane foam; graphene; stress sensor; dielectric; capacitance.

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Hybrid Poly(hydroxyurethane)s as Encapsulation Materials for Photovoltaic: Towards Bio- Based Solutions

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Across all photovoltaic (PV) technologies, organic or inorganic, the encapsulant plays a decisive role in ensuring device integrity and long-term stability. Acting as a barrier against humidity, oxygen, ultraviolet light, and temperature fluctuations, it directly affects the operational lifetime of solar modules. The most established encapsulant, ethylene-vinyl acetate (EVA), owes its success to decades of industrial optimization: it is inexpensive, easy to process, and compatible with large-scale lamination [1]. However, EVA, a fossil-based polymer, suffers from yellowing, loss of transparency, and poor ageing resistance, while its curing temperature (150 °C) may damage temperature-sensitive active layers. These limitations highlight the need for new encapsulation materials that are both durable and environmentally sustainable, reducing the PV industry's reliance on petrochemical-derived resources.
Thermosetting polyurethanes (PUs) offer a promising alternative, being lightweight, cost-effective, and tunable in their mechanical, optical, and barrier properties. Yet, most conventional PUs rely on toxic, fossil- based isocyanates under growing regulatory restriction. In this context, we developed partially bio-based hybrid polyhydroxyurethane (PHU) thermosets as potential encapsulant materials. PHUs are synthesized via isocyanate-free polyaddition between cyclic carbonates and amines [2]. Here, mannitol tricarbonate (MTC), a sugar-derived tricyclic carbonate monomer, was synthesized and reacted with isophorone diamine (IPDA) to form an amino-terminated PHU prepolymer. This prepolymer was blended with poly(propylene glycol) diglycidyl ether (PPG), yielding a castable resin cured into films through an epoxy-amine crosslinking reaction at 80 °C. The resulting materials are highly transparent and exhibit desirable thermal, mechanical, and surface properties. The bio-based origin of MTC, combined with the availability of renewable IPDA grades, supports the development of encapsulants with a lower carbon footprint and strong potential for sustainable PV technologies.
Scheme 1: Synthetic strategy developed in this work.

Keywords: Bio-based encapsulants, Photovoltaic stability, Non-isocyanate polyurethanes, Polyhydroxyurethane thermosets, Transparent bio-based polymers.

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Li-ion conducting Self-Healing Gel Polymer Electrolyte towards high-performance Lithium Battery Applications

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Lithium batteries (LBs) have become the cornerstone of modern portable electronics, electric vehicles, and energy storage systems due to their high energy density, long cycle life, and reliability. However, the safety and longevity of these batteries are significantly hindered by the low thermal stability, leakage issues and low Li transference (approximately 0.3) of the conventional liquid electrolyte [1,2]. Aiming to mitigate these shortcomings, in the current study, a Li-ion conducting self-healing gel polymer electrolyte (SHGPE) has been developed by blending the synthesised self-healing copolymer with the PVDF-HFP matrix via solution casting technique. In the initial stage, UPyMA self-healing monomer was synthesised and characterised. Subsequently, the self-healing copolymer was prepared by integrating AMPSLi, UPyMA, PEGMA, and MBA, through free-radical copolymerization. Then the SHGPE membranes were fabricated by blending the synthesised copolymer into PVDF-HFP matrix with varying amounts of UPy-PEG moieties, which were abbreviated as PUPAM-1, PUPAM-2 and PUPAM-3 [3,4]. Physicochemical characterisations such as ^{1}H NMR, FTIR, XRD, FESEM-EDX, AFM and TGA-DSC confirmed the successful synthesis and copolymer, uniform dispersion of the copolymer within the matrix, along with their thermo-mechanical stability. In addition to this, PUPAM-3 exhibited self-recovery within 6 hours, demonstrating excellent autonomous healing ability. Electrochemical analyses such as EIS, LSV, CV, and chronoamperometry revealed that PUPAM-3 achieved superior Li-ion conductivity (0.5×10^{-3} Scm^{-1}), a higher lithium transference number (0.7), and enhanced electrochemical stability. These results underscore the strong potential of the developed membrane as a robust, self-healing polymer electrolyte for next-generation high-performance lithium battery systems.

Keywords: UPyMA, Polymer electrolyte, Self-healing, Li-ion conductivity, Li-battery.

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SPEEK/PVA based composite polymer electrolyte membrane with modified TiO_2 fillers for application in proton batteries

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Proton batteries, fuel cells and electrolyzers are a few among the myriads of energy storage devices that currently address the need for sustainable energy. These devices use proton conduction to generate energy which is greatly dependent upon the kinetics of the electrolytes present within.[1] Conventional liquid electrolytes although having enhanced proton conduction have grave limitations like flammability, toxicity, corrosiveness, prone to leakage, low thermal stability etc. Solid polymer electrolytes with optimized proton conductivity and thermo-mechanical stability are efficient alternatives for implementation in such devices.[2] In this study, we developed solid composite polymer electrolyte based on a sulfonated poly(ether ether ketone)/poly(vinyl alcohol) blend (SPV) incorporating titanium dioxide (TiO_2) filler modified with both poly(ethylene glycol) (PT), and polyvinylpyrrolidone (PVP) (named as SPV-PPT) via a solution-based route.[3-5] Physicochemical (XRD, FTIR, FE-SEM, TGA, DSC, Mechanical stability, Water Uptake, Oxidative Stability etc.) and electrochemical (EIS, CV, LSV etc.) characterizations were performed for the developed membranes. FTIR confirmed the presence of characteristic functional groups from the polymer matrix and fillers in all the samples. SPV-PPT exhibits the lowest crystallinity (XRD), consistent with disrupted polymer matrix as well as uniform dispersion of fillers, better thermal stability (Compositional change of 51.4 % at 472.7 ºC) and tensile strength of 43 MPa. EIS measurement shows the lowest bulk resistance (Rb) for SPV-PPT, corresponding to proton conductivity of 1.3 x 10−3 S cm−1 at RT. Linear sweep voltammetry further demonstrated its superior electrochemical stability upto 1.63 V. Collectively, the PEG/PVP co-modified TiO_2 promotes effective proton conduction pathways, leading to a composite polymer membrane with optimized thermo-mechanical stability and proton transport suitable for proton battery applications.

Keywords: Proton battery, Proton conductivity, Composite Polymer Electrolyte, Thermo-mechanical stability

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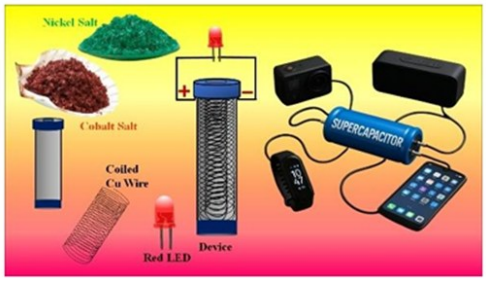
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Synergistic Effect of PDMS Based Hydroxide-Oxide Hybrid Architectures for Supercapacitor Application

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The incorporation of engineered electrodes is an essential component for the advancement of high-power symmetric supercapacitor devices (SSC)[1,2]. Recently, among the various materials, the composite of transition metal oxides and hydroxides has been explored as a highperformance electrode material for supercapacitor devices[3,4]. Herein, this work introduces a compact, leakage-proof, portable, uniquely fabricated symmetric supercapacitor device that utilizes a composite of cobalt oxide and nickel hydroxide (NHCO) as the electrode material, coated on a metal wire that serves as the current collector. Harnessing the complementary properties of $Ni(OH)_2$ and Co_3O_4, here we engineered a hydrothermally synthesized composite with a 3D flower-like/sheet-like hybrid morphology, delivering exceptional charge storage capability. The hierarchical architecture ensures abundant electroactive sites, rapid ion diffusion, and efficient electron transport. Along with this, the unique electrode and device fabrication method integrates flower-like $Ni(OH)_2$ with sheet-like Co3O4, delivering 1485 F g^{-1} at 1 A/g, and the device achieves an energy density of 51.6 Wh/kg at a power density of 1300 W/kg, and maintains 97% capacitance retention after 5000 cycles. Its practical applicability has been shown by the powering of electronic devices, demonstrating its potential for advanced energy storage solutions.



Figures: Composite-based symmetric supercapacitor.

Keywords: leakage-proof; symmetric supercapacitor; hierarchical architecture; energy density; Power density

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Polarity-Controlled Modulation of Piezoelectric Constant and Surface Work-function of PVDF for Dual-Mode Energy Harvesting in Flexible Electronic Applications

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Ferroelectric polymers with high flexibility and inherent piezo, pyro, and ferroelectric properties have gained tremendous importance for next-generation wearable electronics. In this context, we have thoroughly investigated the intrinsic polarity-mediated optimization of multiple parameters such as piezoelectric coefficient, surface roughness, and surface work-function, followed by their effect on piezoelectricity and triboelectricity in poly(vinylidene fluoride) (PVDF) based nanocomposite. By strategically incorporating different concentrations of thermally exfoliated reduced graphene oxide (rGO) into the PVDF matrix, we successfully promoted the formation of the electroactive β/γ-phases, resulting in a significant dual enhancement of charge generation and charge transfer from mechanical stimuli. The incorporation of 2.0 wt.% rGO resulted in the highest polar phase content of approximately 93%, attributed to the uniform dispersion of rGO throughout the polymer matrix. The final hybrid device resulted ~ 7.1 V/cm^2 of pulse open-circuit output voltage density and ~ 0.85 μA/cm^2 of short-circuit current density with ~ 49.8 μW/cm^2 of output power density at ~ 11 MΩ of load resistance. Furthermore, the fabricated device has been demonstrated for flexible electronic applications, functioning as a self-powered active sensor capable of converting external mechanical stimuli into electrical signals for real-time monitoring and control. This study presents a scalable approach and comprehensive insight into multifunctional, dual-mode energy harvesters, highlighting their potential integration into next-generation wearable, flexible, and self-sustained electronic systems.

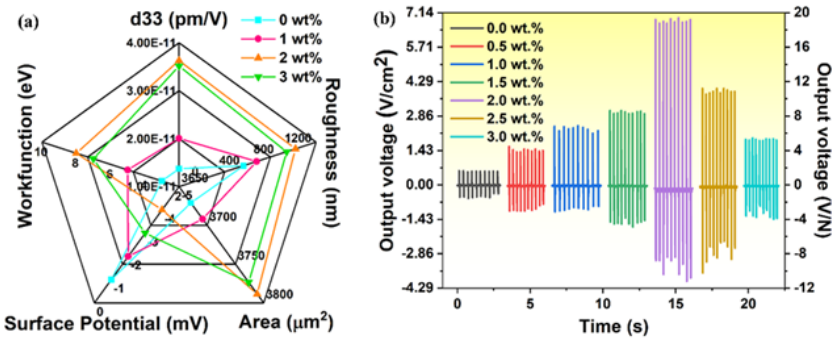


Figure 1: (a) Comparison of different parameters with varying rGO concentration, **(b)** comparison of output voltage density for increased rGO concentration.

Keywords: PVDF, Electroactive phases, Piezoelectricity, Triboelectricity, Intelligent Traffic Monitoring.

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Studies on charged void facilitated stretchable energy harvester

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There is a recent spurt in the development of void engineered energy harvesters based on piezoelectric and triboelectric systems. Herein, we have studied and developed a void engineered piezoelectric-triboelectric hybrid stretchable polymer-based energy harvester. The polymer-based energy harvester was prepared by solvent casting method followed by solvent exchange method. Using the principle, the developed energy harvester was promising in terms of electrical output (~4 V, ~ 3μA) due to synergism of piezoelectricity and charged macro-dipoles in the polymer. Further, triboelectric energy system was coupled with piezoelectric energy to form a hybrid energy system. The applications of these energy harvester were tested in real-life conditions thereby signifying its impact on self-powered energy systems.

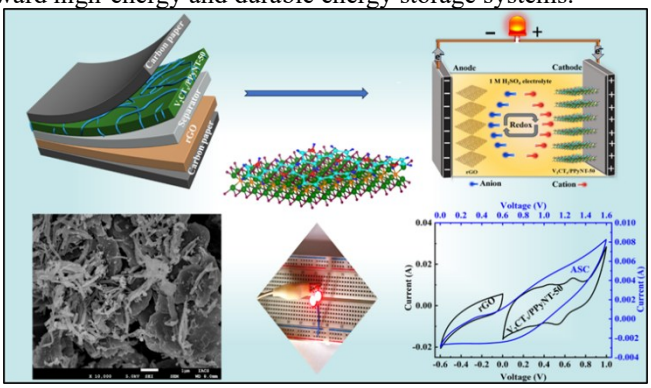
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V_2CT_x/PPy nanotube hybrid nanostructure as anode material towards superior energy storage in aqueous asymmetric supercapacitors

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The development of high-performance asymmetric supercapacitors (ASCs) is critical to bridging the gap between batteries and conventional supercapacitors by simultaneously achieving high energy and power densities[1,2]. In this work, a V_2CT_x/PPy composite was synthesized via in-situ polymerization to exploit the synergistic advantages of MXene nanosheets and polypyrrole nanotubes. The tailored morphology of PPy effectively prevented MXene restacking while enhancing electronic conductivity and structural integrity. To overcome the limited cell potential window of supercapacitor electrodes, an ASC device was fabricated using V_2CT_x/PPyNT-50 as the positive electrode and reduced graphene oxide (rGO) as the negative electrode. The device delivered a remarkable specific capacitance of 89 F g^{-1} at a current density of 1 A g^{-1}, along with a maximum energy density of 114 Wh kg^{-1} and a peak power density of 14,592 W kg^{-1}. Furthermore, it retained 84.4% of its capacitance after 10,000 continuous charge–discharge cycles, demonstrating excellent long-term cycling stability. These results highlight the potential of V2CTx/PPy-based composites for next-generation ASC devices, offering a practical pathway toward high-energy and durable energy storage systems.



Figures 1- Graphical abstract.

Keywords: Supercapacitor, asymmetric supercapacitor, conducting polymer, MXene.

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Hierarchical polyaniline/copper cobalt ferrite nanocomposites for high performance supercapacitor electrode

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Increasing energy demand needs efficient energy storage devices, especially for mobile applications and wearable electronics. Conducting polymer-based nanocomposite offers excellent charge transfer mechanism with high energy storage ability. Herein, we report preparation of polyaniline/copper cobalt ferrite (PANI/CCF) based nanocomposites to fabricate supercapacitor electrodes. In-situ polymerization of PANI ensures the formation of a well-mixed nanocomposite of PANI and CCF. Detailed structural and morphological analysis reveal the formation of a core-shell type structure with CCF as the core and PANI as the shell. The core-shell structure was formed due to the presence of a synergistic interaction between PANI and CCF. Particle size distribution shows a well distribution with an average size ~ 100 – 120 nm, contributing significantly towards high energy density at high power density. The supercapacitor electrode based on 8:1 material shows significantly high capacitance of 408.8 F g^{-1}at a scan rate of 5 mV s^{-1} and 460.1 F g^{-1} at 0.5 A g^{-1} current density. The energy storage capacity enhanced significantly for 8:1 weight ratio of PANI and CCF. The PANI/CCF 8:1 nanocomposite shows energy density of 23 and 18.2 W h kg^{-1} at power density of 150 and 1500 W kg^{-1}, respectively with a good cyclic life (~ 91% retention after the 1500 cycle). Consequently, PANI/CCF 8:1 nanocomposite has excellent potential for supercapacitor electrodes for energy storage applications.

Keywords: Supercapacitor; Energy density; Power density; Polyaniline; Copper cobalt ferrite.

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Fabrication of Polylactic acid (PLA) / Polybutylene adipate-co-terephthalate (PBAT) based 3D Printing Filament

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Three-dimensional (3D) printing is a modern, computer-aided, design-based technology that allows the layer-by-layer deposition of 3D structures. This technique has been extensively developed and optimized and the advances now reside in the development of new materials suitable for 3D printing, which may open the door to new applications [1]. This research discusses on the development of poly(lactic acid) / poly(butylene adipate-co-terephthalate) blend-based 3D printing filaments which represent a significant effort in producing more sustainable and biodegradable materials for 3D printing. Though PLA is suitable biodegradable polymer in 3D printing area having excellent bed adhesion quality, good strength and can be blended or modified with various additives to achieve specific material properties, but its brittle nature and expensiveness make it limit in such area. Hence the filament was fabricated using PLA (40% by weight) and PBAT (60% by weight), with maleic anhydride (MA) employed as a compatibilizer to enhance interfacial adhesion between the two immiscible polymer phases. Acetyl tributyl citrate (ATBC) was incorporated as a biodegradable plasticizer to improve the flexibility and processability of the blend. The compounded materials were melt-blended using a twin-screw extruder and subsequently extruded into 1.75 mm diameter filaments suitable for Fused Deposition Modeling (FDM) applications. The mechanical, thermal, and morphological properties of the developed filament were characterized to evaluate its suitability for 3D printing. Mechanical testing clearly indicated that the blending with PBAT effectively increases the impact strength of PLA along with improved tensile elongation and moderate tensile strength. The incorporation of PBAT and ATBC improved ductility and reduced brittleness. Despite the use of a significant PBAT content, the analysis of thermomechanical properties did not show any significant deterioration in the thermal resistance of the materials, while a detailed differential scanning calorimetry analysis indicates a small tendency to nucleate the PLA structure by PBAT inclusions. The scanning electron microscopy (SEM) analysis of fractured surfaces revealed a transition in deformation mechanism from brittle fracture in pure PLA to a shear yielding behavior in PBAT-rich blends, confirming improved phase compatibility and toughness. The optimized formulation demonstrated balanced strength, flexibility, and printability, highlighting its potential for use in eco-friendly additive manufacturing applications.

Keywords: Poly(lactic acid), Poly(butylene adipate-co-terephthalate), 3D printing, PLA/PBAT blend filament.

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Experimental investigations into direct ink writing of styrene-ethylene-propylene-styrene block copolymer

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Additive manufacturing of thermoplastic elastomers (TPEs) has garnered significant attention due to its ability to produce structurally complex components without the requirement of expensive moulds unlike conventional fabrication techniques. Direct ink writing (DIW) has emerged as one of the key additive manufacturing techniques suitable to 3D print TPE materials overcoming the challenge of filament buckling owing to their soft and flexible structure. However, solvent selection is a crucial step for the DIW process as it significantly governs the material extrudability, print quality and final physicomechanical performance of the additively manufactured parts. Thus, this work primarily focused on the DIW of styrene–ethylene–propylene–styrene (SEPS) triblock copolymer, a promising TPE known for its superior elasticity, thermoplastic processability. Despite its several advantages, SEPS remains underexplored in DIW-based fabrication. To the best of authors' knowledge, this is the first work focusing on the development of a print-ready SEPS ink by selecting a suitable solvent based on Hansen Solubility Parameter analysis. Among all the solvents, toluene was observed to be the most suitable solvent for ink preparation. Rheological investigations were also performed to study the ink behaviour with varying solvent concentration. Viscosity, thixotropic recovery, and extrudate shape stability revealed that the inks containing 35–40 wt% SEPS were suitable for additive manufacturing. Although morphological investigations confirmed good inter and intra-layer coalescence with minimal pore-like defects. Nevertheless, 3D Printed samples were observed to experience anisotropic shrinkage in different directions upon solvent evaporation. The DIW-printed parts exhibited high elongation at break ~ 1000% and a mean tensile strength ~ 6.8 MPa with a hardness of ~ 62 (Shore A). This work highlights the potential of DIW-based additive manufacturing of SEPS-TPE parts with excellent physical and mechanical properties.

Keywords: 3D Printing, Direct ink writing, Styrene-ethylene-propylene-styrene block copolymer, Hansen solubility parameters, Mechanical Properties.

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Upcycling of Postconsumer Recyclate Polypropylene into Low Warping and High Toughness 3D Printable Filaments

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Polypropylene (PP) is widely used in commodity applications owing to its chemical stability, mechanical properties and low cost. However, almost 50% of the produced PP ends up as postconsumer waste (PCW) within a short period of usage.[1] Being a non-biodegradable polymer, recycling PCW PP is important to mitigate plastic waste in landfills.[2] Nonetheless, recycling or upcycling postconsumer recyclate (PCR) PP into valuable resources without deterioration in physical and mechanical properties is a challenge.[3,4] This report presents an approach to upcycle PCR polypropylene (rPP) into high quality 3D printing filament that not only prints with very low warpage but with significantly high elongation at break and toughness. Incorporation of poly(butylene adipate-*co*-terephthalate) (PBAT) along with maleic anhydride grafted polypropylene (MAPP) in specific proportions led to a significant enhancement in mechanical properties, miscibility, crystallization behavior, and 3D printability. rPP/PBAT blends with 20 wt % PBAT and 10 wt % MAPP exhibited a 62-fold enhancement in elongation at break over rPP (from 1.88 to 118.29%) and a 72-fold increase in toughness (from 2 to 143.60 kJ/m^3) with almost similar tensile strength. The final printed components had better layer adhesion and structural stability with a dramatic decrease in warpage, from 25.82% for pristine rPP to only 7.86% for rPP/PBAT blend. Isothermal crystallization studies and data analysis using the Avrami equation showed that crystallization half-time ($t_{1/2}$), which measures the duration needed for half of the total crystallinity to form, increased from 12.6 s for rPP to 66 s for the rPP/PBAT blend. This report demonstrates an approach to upcycle PCR PP, a positive step toward realizing the goals of circular economy and sustainable additive manufacturing.

Keywords: Warpage, toughness, FFF 3D Printing, crystallization.

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Dynamic mechanical analysis of additively manufactured short carbon fiber-reinforced nylon composites across variable printing parameters

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Additive manufacturing of short fiber-reinforced thermoplastics is increasingly adopted for structural applications, yet their viscoelastic behavior remains highly sensitive to processing conditions. This work systematically examines the influence of three printing parameters, namely layer height (0.10, 0.15, 0.20 mm), extrusion temperature (270, 275, 280 °C), and print speed (30, 35, 40 mm/s), on the dynamic mechanical performance of short carbon fiber reinforced nylon composites (SCFRNCs) fabricated by fused filament fabrication (FFF). Dynamic mechanical analysis (DMA) was conducted in three point bending mode. Temperature dependent sweeps at a fixed oscillation frequency were conducted to determine storage modulus (E′), loss modulus (E″), tan δ, and glass transition temperature. To complement experimental characterization, machine learning (ML) models, including random forest regression and artificial neural networks, were trained on the dataset to capture nonlinear relationships between process parameters and viscoelastic properties, and to predict behavior across untested parameter combinations. Initial observations indicate that reduced layer height and elevated extrusion temperature enhance interlayer fusion and fiber to matrix load transfer, thereby raising E′ and shifting Tg, while increased print speed tends to promote porosity and interfacial defects, leading to higher damping. The integration of DMA with machine learning driven prediction provides process–structure–property correlations that can accelerate optimization of additively manufactured SCFRNCs for vibration sensitive engineering applications.

Keywords: Additive manufacturing; Carbon fiber; Nylon composites; Dynamic mechanical analysis; Machine learning.

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Copolymer of C_{20} methacrylate and vinyl acetate as flow modifier for waxy crude

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A series of novel copolymer of eicosyl methacrylate (EMA) and vinyl acetate (VA) {poly(EMA-*co*-VA)} was synthesized *via* free radical polymerization technique to be used as a flow modifier for waxy crude. Different characterization techniques like NMR, FT-IR, Size Exclusion Chromatography (SEC), XRD were employed to characterize these copolymers. From SEC analysis, the molecular weight of poly(EMA-*co*-VA) falls in the range from 4600 to 10,600 g/mol with quite narrow polydispersity index values (<1.5). From rheological and morphological studies, the results showed that poly(EMA-*co*-VA) strongly interacts with wax crystals present in crude. It was also found that monomer ratio greatly impacts decrease of both gelation point and apparent viscosity of crude. With the addition of poly(EMA-*co*-VA) with EMA and VA ratio 2:3, the gelation point of crude oil showed a maximum reduction of 76.2 % at 2000 ppm concentration. However, at lowest temperature, the apparent viscosity of crude oil was reduced by 80.3% at the same concentration. Morphological analysis of wax crystals in waxy crude showed the interaction between polymeric additive and wax, leading to a significant reduction in their size and preventing further growth. These findings offer strong evidence that the synthesized poly(EMA-co-VA) improves the low-temperature flowability of waxy crude oil.

Keywords: Eicosyl methacrylate, flow modifier, molecular weight, polymeric additive, rheology.

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Liquid metal integrated new-generation multifunctional elastomeric composites for soft technological applications

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Liquid metal (LM) integrated elastomeric composites are a breakthrough in soft multifunctional materials (SMMs) having immense transformative potential leveraging innumerable possibilities towards high-end engineering applications. LMs like eutectic gallium-indium alloy mitigate the long-withstanding filler-matrix modulus mismatch issues of a rigid filler-based composite while imparting immense functionality. However, the challenge that remains in the fabrication of such promising materials lie in the fundamental problems of phase incompatibility and lack of interactions between the polymer and the LM, eventually emanating sedimentation of LM resulting in failure in fabrication. In this work, we report a novel binary and ternary composite by integrating eutectic gallium-indium LM alloy and carbonyl Fe particles into a chemically modified block copolymer matrix, resulting in a soft and ultra-stretchable elastomeric material architecture by exploiting the H-bonding interaction of LMs with block copolymer with outstanding multifunctional attributes. Interestingly, the adaptiveness of the LM inclusions towards external mechanical stimuli induces a transition into a 'metallic-elastomer-like' state. The influence of such adaptative microstructure and interfacial interactions result in more than 350% improvement in thermal conductivity, piezo-responsive conductivity evolving into less than 1 Ω.m. resistivity over the neat polymer having more than 50 GΩ.m. resistivity, and high magnetostrictive nature generating over 350 mV of potential in response to mere 0.4 Oe of Ac magnetic field. All of these functionalities are achievable while preserving the compliance of the neat block copolymer with more than 1400% strain at break. This work provides a cost-effective, facile and scalable approach to construct smart multifunctional composites for soft matter technological applications.

Keywords: Liquid Metal; Elastomers; Multifunctional Materials; Interfacial H-bonding.

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A New class of Polymeric material through Inverse Vulcanization: Potential material for rubber composites

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Most of the sulfur produced (derived mainly as a by-product of petroleum refining) has two principal uses: vulcanization of rubber and the manufacture of sulfuric acid. But this abundance calls for new ways of using it. Inverse vulcanization, a procedure that transforms crystalline sulfur into a copolymeric compound by reaction of sulfur with various molecular organic crosslinkers. This process makes Sulfur stable in polymeric form, preventing its conversion back into a brittle crystalline phase that unlocks new functional properties. This research investigates copolymeric sulfur made by inverse vulcanization and its use as a potential crosslinker in carbon black-filled rubbers. The copolymeric sulfur showed increased higher elasticity, and dispersion in rubber compounds than traditionally used sulfur-based cross-linking agents. The composites relate to an interaction between the copolymeric sulfur network and the carbon black reinforcement to evaluate the improvements in the mechanical properties, dynamic performance, and durability of the rubber composites. This study explores the concept of inverse vulcanization as an environmentally friendly method to upcycle elemental sulfur into high-performance polymers. These sulfur copolymers can be used in a range of compounds with the potential of being used effectively in tire, industrial rubber goods, and advanced rubbers. The study effectively advances both environmental sustainability and technological improvements in rubber science by recycling excessive sulfur into value-added functional materials.

Keywords: Sulfur, inverse vulcanization, Natural Rubber, Carbon black, Composites.

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ZnO-Functionalized Carbon Dots Reinforced PMMA-g-NR Nanocomposites as an Efficient Absorbent for Industrial Dye Removal

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In this study, nanocomposites consisting of polymethyl methacrylate (PMMA) grafted onto natural rubber (NR) and zinc-functionalized carbon dots (Zn-f-CDs) were created using a solution mixing technique followed by the casting of a solvent. Before the fabrication of the nanocomposites, Zn-f-CDs with varying concentrations of ZnO were produced through a hydrothermal process[1,2]. Among those tested, Zn-f-CDs-5 was chosen for nanocomposite fabrication due to its ideal fluorescence intensity, excellent colloidal stability, and enhanced surface functionalization. High-resolution transmission electron microscopy (HRTEM) confirmed the successful integration and even distribution of Zn-f-CDs-5 within the PMMA-g-NR matrix, while field emission scanning electron microscopy (FESEM) and energy dispersive X-ray analysis (EDAX) were used to characterize the morphology and elemental composition of the Zn-f-CDs[3]. The addition of 4 phr of Zn-f-CDs- 5 into PMMA-g-NR led to an impressive 87% increase in tensile stress and a notable enhancement in storage modulus, which can be attributed to the strong interactions between the polar functional groups of Zn-f-CDs and the PMMA-g-NR chains. This observation was further corroborated by a shift in the glass transition temperature (Tg) from −58 °C to −54 °C[4]. The thermogravimetric analysis indicated that the initial degradation temperature, peak degradation temperature, and residue percentage at 700 °C of PMMA-g-NR increased consistently with the loading of Zn-f-CDs-5, suggesting a delay in thermal degradation due to improved interactions between the rubber and filler. The uniform distribution of Zn-f-CDs and the establishment of robust filler–matrix networks led to enhancements in the mechanical, dynamic mechanical, and thermal properties of the nanocomposites. These results underscore the potential of Zn-f-CD-reinforced PMMA-g-NR nanocomposites for advanced material applications that demand high mechanical strength and thermal stability.The nanocomposite exhibited remarkable dye adsorption, achieving up to 82% removal of Rhodamine B (RhB) in 72 hours under dark conditions, due to the high surface area and functional group density of Zn-f- CDs[5]. Overall, the Zn-f-CDs/PMMA-g-NR nanocomposite exhibits a synergistic enhancement in structural and environmental performance, making it a promising candidate for advanced applications in wastewater treatment and sustainable functional materials.

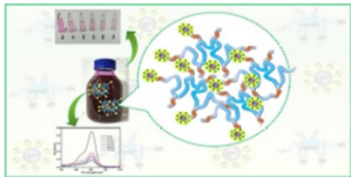


Figure 1– Graphical representation of ZnO functionalized Carbon Dots incorporated PMMA-g-NR Nanocomposites as an Efficient Absorbent for RhB dye.

Keywords: Nano Composites, ZnO functionalization, Carbon dots, PMMA-g-NR, Absorption, Dye removal.

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New Sustainable Crosslinking System for Fluoroelastomers

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Traditionally, bisphenol derivatives served as the primary crosslinking system for certain fluoroelastomers, notably FKM. However, these systems posed ecological and health concerns, including issues such as endocrine disruption and reproductive disorders. To address these drawbacks, our objective was to identify an alternative, environmentally friendly crosslinking system that could offer superior cure characteristics and physico-mechanical properties. In pursuit of this goal, 2-methyl resorcinol was investigated as a potential curative to achieve rheological and mechanical properties comparable to those obtained with the conventional bisphenol AF crosslinking system. Rheometric studies demonstrated that optimal cure properties were achieved by using 2-methyl resorcinol as the curative, alongside benzyl triphenyl phosphonium chloride (BTPPC) as the phase transfer catalyst. Dimethyl sulfoxide (DMSO) served as the dispersion medium for 2-methyl resorcinol in the FKM elastomer matrix. The best cure and physico-mechanical properties were observed when employing 0.5 parts per hundred (phr) of 2-methyl resorcinol 467.6 ± 0.06 μM, is far lower when compared to the conventional bisphenol AF crosslinking system, which has an IC_{50} of 73.4 ± 0.03 μM.

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Green Synthesis of Lignin-Capped Silver Nanoparticles and Their Antibacterial and Antioxidant Evaluation

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A facile and green approach was developed for synthesizing lignin biopolymer–based silver nanoparticles (LS-AgNPs) using sodium lignosulfonate as an eco-friendly reducing and capping agent. Reaction parameters such as pH, temperature, time, and precursor concentration were optimized to achieve a rapid and reproducible synthesis. The formation of LS-AgNPs was confirmed through UV–Vis spectroscopy, particle size analysis, XRD, FTIR, and TEM, revealing spherical nanoparticles of approximately 24 nm with a face-centered cubic (FCC) crystalline structure. The minimum bactericidal concentrations (MBCs) were found to be 4 ppm for S. aureus and 6 ppm for E. coli, while the antioxidant activity exhibited an IC_{50} value of 34.37 µg/mL. The study demonstrates that lignin effectively facilitates silver ion reduction and nanoparticle stabilization, yielding biocompatible, multifunctional AgNPs. This green route offers a sustainable strategy for producing functional silver nanoparticles with reduced toxicity and potential applications in biomedical and polymer-related fields.

Keywords: Lignin biopolymer; Silver nanomaterials; Eco-synthesis; Antimicrobial; Antioxidant.

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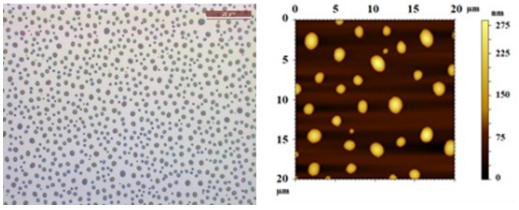
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Miniaturization and Controlled Suppression of Polymer Thin Films on PDMS Embedded with In Situ Reduced Gold Nanoparticles

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Polystyrene (PS) thin films were fabricated by spin coating a PS solution in toluene onto polydimethylsiloxane (PDMS) substrates functionalized with in situ reduced gold nanoparticles (Au NPs). The films underwent spontaneous rupture driven by interfacial van der Waals interactions and disjoining pressure. The stability and dewetting behavior of the polymer films were systematically investigated as a function of Au NP reduction time, which was varied from 6 to 48 hours. Upon rupture, the films initially developed holes that expanded and coalesced into a continuous threadlike network. This network subsequently fragmented, yielding an isotropic array of nearly monodisperse droplets. Both the droplet diameter (d^D) and the characteristic spacing (λ^D) exhibited a systematic dependence on the Au NP reduction time. Furthermore, the characteristic length scale (λ^D) and droplet diameter (d^D) of the dewetted structures were found to be tunable by varying the nanoparticle reduction time within the PDMS substrate. Morphological parameters, including droplet height (h^D), diameter (d^D), and periodicity (λ^D), were quantified. Complete stabilization of the PS films was not achieved, even after 48 hours of Au NP reduction. Thermal annealing experiments were performed for durations ranging from 5 minutes to 192 hours, and the resulting surface morphologies were characterized using optical microscopy and atomic force microscopy (AFM). All films on Au NP–reduced PDMS substrates exhibited complete dewetting, resulting in the formation of droplets. A progressive decrease in both λ^D and d^D was observed for films on PDMS substrates reduced for 48 hours, whereas films on 12-hour reduced substrates displayed larger droplet sizes and reduced periodicity. Contact angle measurements were recorded for all substrates, revealing a decrease in contact angle with increasing annealing time. The non-monotonic variation of λ^D and d^D with nanoparticle reduction time is not yet fully understood and warrants further investigation.



Figures 1 – Optical and AFM images of dewetted morphology of PS film on in situ reduced Au NPs in PDMS.

Keywords: Polymer Thin film, gold nanoparticles, in situ reduction, PDMS.

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Biodegradable, mechanically strong, and water-stable drinking straws based on crosslinked modified cellulose-chitosan composites

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Single-use plastic straws are a major environmental concern, as they do not degrade easily and contribute to heavy pollution, harming the ecosystem and natural life[1]. Paper and polylactic acid are considered greener options, but they fall behind single-use plastic straws in terms of poor water stability and strength. Apart from this, the paper straws are only partially biodegradable[2]. This work presents a more sustainable alternative; the biodegradable straws made from rice straw-based cellulose and chitosan, both being byproducts or waste sources of polymer. The rice straw cellulose was obtained through delignification and further oxidised with Ammonium persulfate (APS). Chitosan was dissolved in 1% acetic acid solution to generate a positive charge on it. The negative charge on oxidised cellulose and the positive charge on chitosan are used to improve the performance of the straws[3]. Among the prepared straws, the formulations, the DRSSO_Ch3-7 composite (oxidised rice husk cellulose (3 wt%): chitosan (7 wt%)) shows the best results with a flexural strength of ~17.2 MPa, flexural modulus of ~345 MPa, and tensile modulus of ~175 MPa. It also displayed excellent water resistance, remaining stable for up to 24 hours, with a hydrophobic surface contact angle of 112.8° and a migration value of ~1856 µg/kg. The improved characters were attributed to the electrostatic interaction and the crosslinking of chitosan's amine group with glutaraldehyde. Importantly, biodegradability tests confirmed that the straws break down naturally over time, making them environmentally safe. Overall, these rice husk-based straws combine strength, stability, and sustainability, offering a viable and eco-friendly alternative to conventional plastic and paper straws. Looking ahead, efforts will focus on refining the process and moving toward large-scale production.

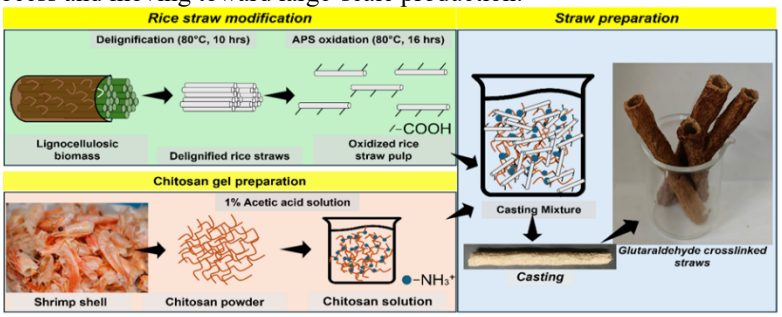


Figure 1. Graphical abstract of straw production.

Keywords: oxidation, crosslinking, LCA, sustainable, renewable.

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Solid State Synthesis, Characterization and Energy Storage Application of PoPD@CMS Nanocomposites

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In the recent past, it is witnessed that the global energy demand is increasing steadily. To address this issue, various energy generation and storage applications have been given special attention for more than four decades [1]. Among these, supercapacitors play a vital role as promising candidates for electrical energy storage in solid-state devices due to their superior power density, long cycle life, remarkable specific capacitance, high safety, and fast charge/discharge rates, which can overcome many drawbacks of batteries. A review of the literature reveals that, in supercapacitors, organic conjugated polymers have exhibited remarkable multifunctional characteristics. [2,3] This research provides insight into the synthesis of poly(o-phenylenediamine)-doped carbon microspheres (PoPD@CMS) as efficient electrode materials for supercapacitor applications. The PoPD contains a higher number of nitrogen-containing functional groups, which contribute to greater capacitance. Doping the carbon microspheres further enhances the specific capacitance due to their good electrical conductivity and thermal stability.[4] The synthesized nanocomposites were characterized using XRD, FT-IR, SEM, and NMR spectroscopic techniques, which revealed its morphology, structure, surface area, and crystallinity. Electrochemical studies using cyclic voltammetry (CV), galvanostatic charge–discharge (GCD), and electrochemical impedance spectroscopy (EIS) were conducted to investigate the electrochemical characteristics and capacitance. The control PoPD electrode exhibited a higher specific capacitance of 173 F g^{-1} at 1 A g^{-1}. Furthermore, the incorporation of carbon microspheres into the polymeric membrane at different weight loadings demonstrated excellent performance, making these composites promising candidates for energy storage applications.

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Environmental stable graphene oxide/magnesium oxide nanoparticles/methyl cellulose nanocomposite films and morphological analysis

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Nanoscale fillers have been extensively used[1-2] in various applications in recent decades. Their preparation and use in industry, agriculture, and medicine have improved. One of these promising materials is magnesium oxide (MgO),[3-4] which has unique characteristics that make it appropriate for many applications. Trigonella foenum-graecum leaf extract is used to synthesize magnesium oxide nanoparticles (MgO NPs) sustainably. Green production of MgO nanoparticles using Trigonella foenum-graecum is simple and suitable for biological applications. This nanoparticle construction technology is suitable for antibacterial studies. The precursor to Trigonella foenum-graecum, magnesium chloride, reduces and stabilizes. Functional groups were confirmed using FTIR.GC-MS confirmed the leaf extract's stabilizing and decreasing functional groups, as well as the influence of green MgO nanoparticles on both gram-positive and gram-negative bacteria. MgO nanoparticles were found to be antibacterial against both strains.

Keywords: Magnesium oxide nanoparticles; Biosynthesis; Graphene Oxide.

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Waste-Derived Cellulose Nanofiber Reinforced Polysulfone Membrane for Efficient Lead ion (Pb^{2+}) removal

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Lead contamination (Pb^{2+}) of water remains a persistent public health and environmental issue due to its toxicity, persistence, and tendency to bioaccumulate. Conventional treatments face cost, regeneration, and secondary-pollution challenges, motivating development of low-cost, sustainable, polymeric membranes. In this study, cellulose nanofibers (CNFs) derived from waste office paper by alkaline hydrolysis were employed as hydrophilic fillers in the fabrication of polysulfone (PSf) membranes. A novel PSf-CNF blend membrane was developed using phase inversion method, incorporating polyvinylpyrrolidone (PVP) as a pore-forming agent to enhance porosity and hydrophilicity. Membranes with different CNF loadings were fabricated and tested for their pure water flux and lead ion (Pb^{2+}) rejection efficiency. The surface morphology and structure of the membranes were characterized using field emission scanning electron microscopy (FE-SEM), Fourier transform infrared spectroscopy (FTIR) confirmed incorporation of CNF functional group, and contact angle measurements indicated increased hydrophilicity. The incorporation of low concentration of CNF (0.3 wt%) significantly enhanced membrane performance, achieving a pure water flux of 70 LMH, higher than the pristine PSf membrane. The improvement is attributed to increased hydrophilicity, better pore distribution, and the synergistic role of CNF in enhancing water transport channels. With an increase in concentration of CNF (0.5 wt%), the pure water flux value decreased, while Pb^{2+} rejection increased to 70.45%. These preliminary results demonstrate the potential of waste-derived CNF as low-cost, sustainable additive to enhance PSf membrane performance for heavy metal contaminated wastewater.

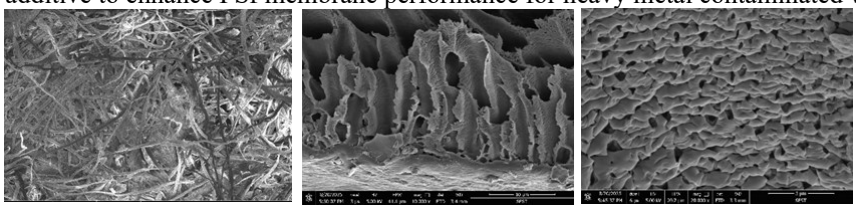


Figure: FE-SEM image of (a) CNF after alkaline hydrolysis (b) membrane cross section and (c) surface of 0.3% CNF.

Keywords: Cellulose nanofiber, waste-derived membranes, polysulfone membrane, Heavy metal removal, Polymeric membrane.

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Poly(vinyl) Alcohol Modified Gel Polymer Electrolyte with Imidazole Dendrimer Functionalized MWCNT for Energy Storage Application

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The development of efficient and sustainable technologies for the fabrication of supercapacitors using an active polymer membrane and electrode materials is an active area of interest[1]. Especially, in the recent past, a higher population country like India has been paying severe attention to the fabrication of efficient supercapacitor devices for energy storage applications. Specifically, the need for fabrication of effective, reasonably priced, and environmentally friendly energy solutions is increasing as the world's energy demands grow. Although batteries are commonly used, their limited lifespan and slow charge-discharge rates restrict their application. In this context, supercapacitors have become attractive options for future energy storage due to their high-power density, rapid charge-discharge capability, and extended cyclic stability[2]. In this study, three generations (G0, G1, and G2) of imidazole functionalized dendrimers were covalently functionalized on MWCNT, thus producing IMD-MWCNT. The synthesized materials were characterized using XRD, FTIR, FESEM, and EDAX techniques. Then, these hybrids were used individually for the fabrication of corresponding working electrodes of IMD-MWCNT, and subsequently they were analyzed under identical experimental conditions by cyclic voltammetry (CV), galvanostatic charge-discharge (GCD), and Electrochemical Impedance Spectroscopy (EIS). Based on the above results, it is inferred that G1 has exhibited superior performance as compared to G0 and G2, and it yielded a specific capacitance of 1480 F/g at a current density of 1A/g. Further investigation of the cyclic stability of IMD-MWCNT(G1) through galvanostatic charge/discharge tests showed an 80% retention of capacitance after 1000 cycles. The asymmetric supercapacitor IMD-MWCNT(G1)//MWCNT was analyzed using Poly(vinyl) alcohol Modified Gel Polymer as electrolyte and separator, resulting in high energy and power density. Consequently, the newly fabricated electrode represents a promising one for the fabrication of supercapacitor electrodes.

Keywords: MWCNT, Dendrimer, polymer, supercapacitor, specific capacitance, high energy density.

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Reduced Graphene Oxide and Copper-Metal Organic Framework Based Hybrid Nanocomposites of Poly (vinylidene fluoride) for Energy Harvesting and Piezocatalysis Applications

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Poly (vinylidene fluoride) (PVDF) and its nanocomposites show promising piezoelectric energy harvesting and piezocatalytic water remediation capabilities. In this study, PVDF nanocomposites were prepared by incorporating a hybrid nanofiller of reduced graphene oxide (RGO) and Copper-Metal Organic Framework (Cu-MOF) through melt-mixing. Nanocomposite with 1.5 wt.% hybrid nanofiller concentration (PGM-1.5) showed a maximum polar phase fraction of ~ 97.2 %. The enhancement of polar phase content was attributed to the Cu-MOF graphene nanofiller, promoting better dipole alignment in the PVDF matrix through multifaceted interfacial interactions[1]. The piezoelectric energy harvesting device prepared using this composite generated an open-circuit voltage (V_{oc}) of ~ 58.3V, a peak-to-peak voltage (V_{p-p}) of ~ 88.9V, and a high power density of 52.7 μW/cm². Additionally, the piezocatalytic capability in these nanocomposite films facilitated the degradation of Cr (VI) ions in Potassium Dichromate into relatively harmless Cr (III) ions, with a removal efficiency of ~ 48.3% under mechanical ultrasonication in the absence of light[2,3]. These findings pave the way for innovative hybrid filler composite materials for applications in sustainable energy solutions and environmental remediation technologies.

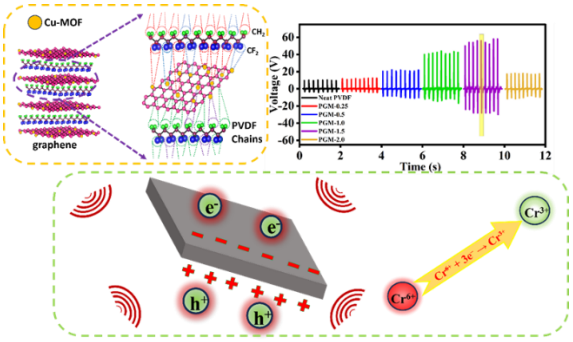


Figure 3 Schematic showing the interaction between Cu-MOF, RGO and PVDF chains, piezoelectric performance of PENG device and the mechanism of piezocatalytic degradation of hexavalent chromium ions via the PGM nanocomposite.

Keywords: PVDF, Cu-MOF, RGO, Piezoelectric nanogenerator, piezocatalysis, Water remediation.

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Effects of few-layered graphene encapsulation on morphology and mechanical properties of Polyamide 6 nanocomposites

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Few-layered graphene (GrapheneBlack 3X) and expanded graphite (EG 3806) were incorporated into polyamide 6 (PA6) matrix separately through melt-mixing using a conical micro-compounder. Prior to melt-mixing, graphene and EG were ultra-sonicated in N-methyl-2-pyrrolidone (NMP)[1,2], enabling PA6 granules to be encapsulated with few-layered graphene and EG[3]. Structural and morphological characterization were performed using wide-angle X-ray diffraction, Raman spectroscopy, and X-ray photoelectron spectroscopy, along with optical, scanning electron microscopy, and transmission electron microscopy, all of which verified the presence of uniformly dispersed graphene sheets. Mechanical studies showed that the EG 3806 grade notably improved the Young's modulus, reaching ~ 1.5 GPa at 3.5 wt.%, while nanoindentation measurements recorded a hardness value of ~ 180 MPa and a modulus of ~ 2.5 GPa for EG 3806 nanocomposite, compared to ~ 150 MPa hardness and ~ 2 GPa modulus for pristine PA6. Furthermore, dynamic mechanical thermal analysis revealed an enhanced storage modulus of ~ 3.7 GPa at 120 °C for PA6/EG nanocomposite. These improvements are attributed to the efficient dispersion of few-layered graphene within the PA6 matrix, highlighting the promise of PA6/graphene nanocomposites in applications that demand superior mechanical performance.

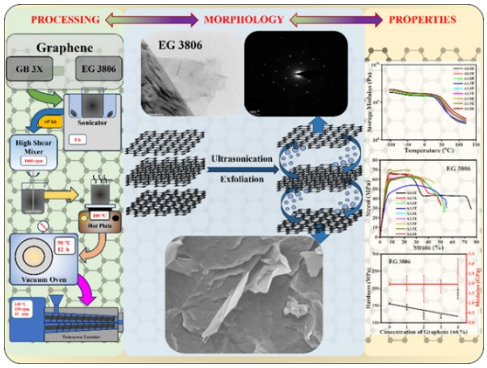


Figure 1: PA6/graphene nanocomposites: Processing, morphology, and mechanica; properties.

Keywords: encapsulation, melt-mixing, nanocomposites, graphene, PA6.

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Polymer Based composites for Future Packaging Materials

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Packaging is an important element in today's industries that provide product protection, shelf-life enhancement, and convenience for consumers. Polymer-based composites are becoming a promising alternative to traditional packaging materials because of their lightweight, strength, and better barrier properties. These products not only solve problems concerned with waste production and recyclability but are also helpful towards environmentally friendly packaging solutions. All major food, pharma, cosmetic, and e-commerce sectors require the packaging materials that offer higher moisture, oxygen, and UV barriers as well as enhanced functions such as resealable and tamper-resistant designs. Packaging sustainability has driven the use of biodegradable and recyclable polymers, such as polylactic acid (PLA), polyhydroxyalkanoates (PHA), and post-consumer recycled plastics. Advances like active and intelligent packaging also enhance product safety by using antimicrobial agents and freshness indicators. Composites based on polymers also enhance packaging mechanical strength, flexibility, and impact resistance, saving material usage without compromising performance. The use of nanomaterials improves barrier properties, while biopolymer reinforcements allow for environmentally friendly solutions. With global regulations driving towards more environmentally friendly packaging options, polymer composites provide a sustainable, high-performance solution. Their versatility in recyclability, biodegradability, and smart functionalities makes them the future of sustainable packaging, enabling the shift towards a circular economy.

Keywords: Polymer based composites, Biopolymer, Nanocomposite packaging, Mechanical properties.

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Pistachio Shell Powder Incorporated Chitosan Biocomposite Film for Eco-Friendly Packaging: Synthesis and Characterization

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Chitosan (Cs) is a biopolymer known for its high biocompatibility, biodegradability, and antibacterial properties. Pistachio shells, considered biowaste, are also environmentally friendly, biodegradable, and non-toxic in nature. The combination of these two biomaterials can lead to the development of a hybrid biocomposite with intriguing functional properties. In this work, a series of biocomposites made with chitosan (Cs) and pistachio shell powder (Ps) were prepared. The films of these composites were fabricated using the solvent casting method. The physico-mechanical properties of these biocomposite films were evaluated using FTIR, XRD, DSC, TGA, SEM, and UTM analyses. Their barrier properties were assessed by measuring moisture content, water vapour permeability, swelling percentage, and transparency, with the intention of exploring their potential use in packaging applications. Among all the samples, the biocomposite film containing 20% pistachio shell powder exhibited the highest mechanical properties as compared to the other biocomposite films. Additionally, the chitosan film with 40% pistachio shell powder exhibited a lower moisture content (10.76%) than the pure chitosan film (14.39%). The incorporation of pistachio shell filler significantly influenced the water vapour permeability (WVP) of biocomposite films. The film containing 40% filler also displayed the lowest swelling ratio, whereas the pure chitosan film exhibited the highest amount at a specific time. This has also been observed that the filler amount gradually enhances the thermal stability of biocomposite films. The biocomposite film with 40% filler exhibited the highest thermal stability compared to the other biocomposite films. The evaluated properties of these films indicate that these biocomposites are suitable for use in food packaging.

Keywords: Chitosan; biopolymer; pistachio shell; biocomposite; food packaging.

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Polyaniline/Acetylene black/OMMT Ternary nanocomposite as a bifunctional material for environmental remediation and energy storage

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Rapid industrialization brings environmental risks and challenges for energy demands, making sustainable practice essential. Advanced materials with multi-functional properties often offer a sustainable solution. Herein, we report the development of a ternary nanocomposite consisting of polyaniline (PANI), acetylene black (AB), and organically modified montmorillonite (OMMT) as a bifunctional material - an adsorbent for dye removal from wastewater and an electrode material for a symmetric supercapacitor (SSC). The effective removal of hazardous methyl orange (MO) dye was explored using the ternary nanocomposite PANI/AB/OMMT with weight ratios 2:1:1, 4:1:1, 8:1:1, and 10:1:1 as an adsorbent. The nanocomposite PANI/AB/OMMT(8:1:1) showed the highest adsorption capacity, attributed to its large surface area, high positive surface charges, and unique morphology. Adsorption data is best fitted with the Redlich-Peterson isotherm and pseudo-second-order kinetics model, suggesting that the adsorption controlling step is chemisorption. The analysis of thermodynamics demonstrates that the adsorption process was spontaneous and endothermic. The nanocomposite PANI/AB/OMMT(8:1:1) shows a maximum adsorption capacity of 564 mg/g for MO dye. The adsorption mainly occurs through electrostatic interaction, hydrogen bonding, and π-π interaction at adsorbent/adsorbate interfaces. The PANI/AB/OMMT(8:1:1) nanocomposite showed specific capacitance of 232 F/g and 444 F/g before and after dye adsorption, respectively. The increase in capacitance after dye adsorption may be due to increased nitrogen and oxygen content. Further, the SSC based on PANI/AB/OMMT(8:1:1) nanocomposite, fabricated using PVA/H_2SO_4 gel electrolyte, shows energy density of 27.73 and 53.1 Wh/kg before and after dye removal, respectively. Additionally, both SSC devices exhibit capacitance retention of 87% and 96% after 8000 cycles.

Keywords: polyaniline, acetylene black, organically modified montmorillonite, dye removal, symmetric supercapacitor.

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Nano-engineered Chitosan & TiO_2 fillers based UHMWPE Composites for Next Generation Orthopaedic Implants

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Ultra-high molecular weight polyethylene (UHMWPE) is extensively used in orthopaedic implants owing to its excellent biocompatibility, low coefficient of friction, and superior wear resistance.[1] However, its long-term clinical performance is compromised by the generation of wear debris during articulation, which necessitates the development of reinforced composites with improved properties.[2][3] In this research, UHMWPE (U) based bio-composites were fabricated by incorporating 2 wt.% chitosan (CHS) and 3 wt.% TiO_2 to obtain four formulations, i.e. U, UCHS, UTiO_2 and UCHSTiO_2, via compression molding at ~220 ºC and ~10 MPa for ~1 hour. All the composites exhibited improved performances, with UCHSTiO_2 composite demonstrated highest densification (~99.89%) and better hardness (~81.77% higher) and superior modulus of elasticity (~86.44% higher) than that of pristine U. Fretting wear tests also revealed the lowest wear rate of 1.1×10^{-5} mm^3/Nm (~78% lower than U) and the lowest coefficient of friction. Plasticity index (r_e) and dissipation energy (r_d) were analyzed to elucidate deformation behavior under load, while wear volumes and rates were simultaneously quantified for all composites. Antibacterial assays against *E. coli* and *S. aureus* confirmed activity in all composites, with UCHSTiO_2 demonstrating the strongest bacterial inhibition, supported by SEM micrographs. These synergistic enhancements establish UCHSTiO_2 as a promising load- bearing implant material with superior durability and clinical potential.

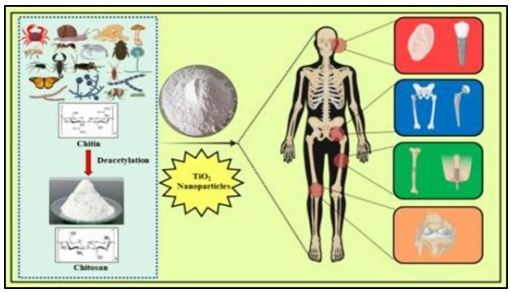


Figure: Illustrating the biomedical applications of chitosan & TiO_2.

Keywords: Ultra-high molecular weight polyethylene, chitosan, TiO2, mechanical properties, tribology.

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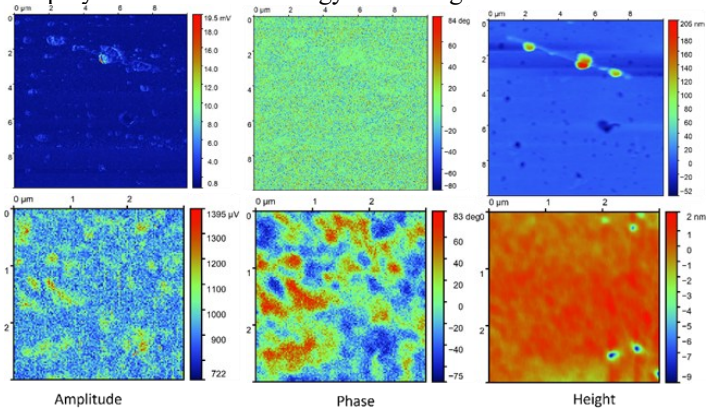
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Nanoscale Ferroelectric Domain Evolution and Piezoelectric Performance in PVDF/ZnO Polymer Nanocomposites

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Understanding the nanoscale ferroelectric domain behavior of polymer–inorganic hybrid systems is crucial for advancing high-performance piezoelectric materials. In this work, poly(vinylidene fluoride) (PVDF) and PVDF/ZnO polymer composites with varying nanorod loadings were fabricated to correlate structure, domain evolution, and electromechanical response. ZnO nanorods were synthesized via a surfactant-assisted low-temperature hydrothermal method, ensuring controlled morphology and high aspect ratio, while polymer hybrid membranes were cast using an automatic film applicator to obtain uniform thickness and long, defect-free sheets suitable for device integration. Piezo force microscopy (PFM) provided direct insights into nanoscale ferroelectric switching, revealing that pristine PVDF exhibits weak, randomly distributed domains, whereas ZnO incorporation (1–5 wt%) induces well-defined 180° phase contrast and significantly enhanced amplitude signals, indicative of stabilized β-phase and improved dipole alignment. At higher filler content (10 wt%), domain activity was suppressed due to agglomeration and disrupted polymer–filler interactions. Supporting characterizations confirmed these observations: FTIR spectra showed progressive β-phase enhancement, FESEM revealed homogeneous dispersion at moderate loadings, and dielectric analysis demonstrated interfacial polarization–driven permittivity enhancement. These findings highlight ZnO nanorod-driven nanoscale ferroelectric domain engineering in PVDF, offering promising strategies for flexible, self-powered polymer sensors and energy harvesting devices.



Figures 1: In-plane PFM analysis of PVDF/5 wt% ZnO nanorod composite: amplitude, phase, and magnitude images.

Keywords: Ferroelectric domains, PVDF/ZnO nanocomposites, Nanoscale engineering, β-phase enhancement.

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Nacre-Inspired Modified Boron Nitride Nanosheets Integrated Poly(3-hydroxybutyrate) Nanofibers for Enhanced Piezoelectricity

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The piezoelectric effect refers to the ability of certain materials to convert mechanical energy into electrical energy when subjected to physical stress.[1] Piezoelectric polymers are widely used owing to their flexibility; however, their piezoelectric response is generally weaker than that of ceramic materials. Among these polymers, poly(vinylidene fluoride) (PVDF) is the most extensively studied, but its high fluorine content and toxic degradation products raise biocompatibility concerns. To address this limitation, biodegradable polymers have emerged as attractive alternatives for piezoelectric applications, although their piezoelectric performance remains relatively poor. To enhance the response of such polymers, strategies including in situ poling during electrospinning to promote piezoelectric phase formation, as well as the incorporation of piezoelectric fillers, have been employed.[1,2] In this study, we report a strategy for fabricating oriented piezoelectric nanofibers by incorporating modified boron nitride nanosheets (G-BNNSs) into poly(3-hydroxybutyrate) (PHB) via electrospinning. The effect of varying G-BNNSs concentrations on the piezoelectric properties of PHB nanofibers was systematically investigated. A synergistic interaction between the G-BNNSs and the aligned molecular dipoles of PHB resulted in a fivefold enhancement in piezoelectric performance, yielding a peak-to-peak open-circuit voltage of 14.2 V. This work presents a promising approach for developing high-performance, biodegradable piezoelectric nanogenerators with strong potential for biomedical applications.

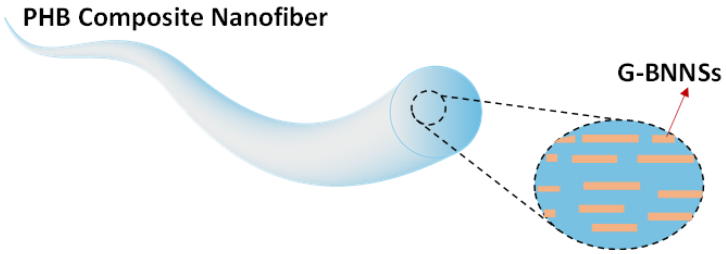


Figure 1: Schematic representation of PHB composite nanofiber.

Keywords: poly(3-hydroxybutyrate), piezoelectric, boron nitride nanosheets.

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Designing lightweight and flexible polymeric nanocomposites for EMI Shielding applications via the incorporation of one-dimensional nanomaterials

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Electronic devices such as laptops, tablets, smartphones, and many more have become absolutely necessary in today's world, but they also play a significant role in electromagnetic interference (EMI), which can seriously endanger human health in addition to interfering with device functionality [1]. Therefore, EMI Shielding is very important to guarantee that electronic devices operate smoothly and to reduce the risk to human life [2]. Nanocomposites made of conductive thermoplastic elastomer (TPE) have emerged as a material that is becoming increasingly effective in mitigating unwanted electromagnetic waves. As a result, these nanocomposites have the potential to be utilised as an effective material for electromagnetic interference shielding.[3]. This work explores a conductive TPE based nanocomposite of EPDM/ LDPE blends which has been filled with a one- dimensional nanomaterial such as MWCNT as the conducting nanofiller. The nanocomposites which were prepared via a dual mixing strategy (melt mixing of EPDM/LDPE blends followed by solution mixing with the MWCNT nanofiller) exhibited good MWCNT dispersion and a robust conductive network. A percolation threshold which is achieved at 3 wt.% MWCNT shows a jump in DC conductivity value from 10^{-10} to 10^{-6} S/cm, after which the DC conductivity increases more gradually instead of showing a sharp rise. The nanocomposite exhibited highest DC conductivity value of 10^{-2} S/cm at 10 wt.% MWCNT showing that the conductivity increases with increase in filler concentration. Thermal conductivity values also show a similar trend with a highest of 0.3987 W/mK which was exhibited by the nanocomposite with 10 wt.% MWCNT. With respect to EMI Shielding which was measured in the X-band (8.2-12.4 GHz), the nanocomposites exhibited an EMI Shielding Effectiveness (EMI SE) of -20.95 dB at 10 wt.% MWCNT loading, thereby blocking 99% of the electromagnetic waves, which means only 1% of the electromagnetic waves is transmitted, thereby signifying that the nanocomposites synthesized can be utilized for EMI Shielding applications[4]. These findings demonstrate that EPDM/LDPE/MWCNT nanocomposites are lightweight, flexible, and reasonably priced materials for multipurpose applications and advanced EMI shielding, satisfying the needs of contemporary electronic and communication devices.

Keywords: EMI Shielding, nanocomposites, MWCNT, EPDM/ LDPE blends, percolation threshold.

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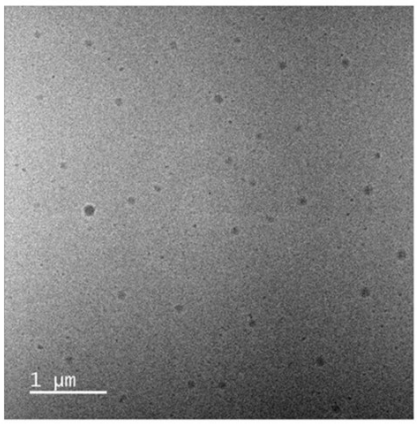
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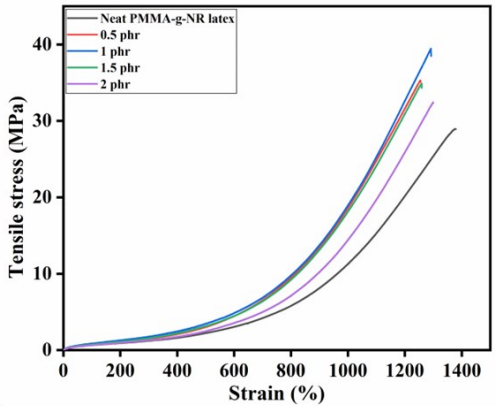
Bacterial cellulose-based carbon dots: A potential reinforcing filler for polymethyl methacrylate-grafted-natural rubber latex

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This study explores the reinforcing effect of carbon dots (CDs) in poly (methyl methacrylate)-grafted-natural rubber (PMMA-g-NR) latex. CDs were synthesized by using bacterial cellulose, citric acid, and cysteamine hydrochloride as precursors via a hydrothermal process, in which different functional groups, such as hydroxyl (-OH) groups, thiol (-SH), amine ($-NH_2$), and carboxylic acid (-COOH) groups, were introduced onto the surface of the CDs (1). Subsequently, different concentrations (0.5, 1, 1.5, and 2 phr) of CDs were incorporated into the PMMA-g-NR latex via solution mixing method to prepare PMMA-g-NR latex-CD nanocomposites. The effect of incorporation of CDs on the physico-mechanical properties of the PMMA-g-NR latex were investigated. Notably, the maximum tensile strength increased from 28 MPa (neat PMMA-g-NR latex) to 39.5 MPa (PMMA-g-NR latex containing 1 phr of CDs), which suggests that the incorporation of 1 phr of CDs resulted in a 1.4-fold increase in the maximum tensile strength. The significant enhancement in the maximum tensile strength of PMMA-g-NR latex by the incorporation of CDs was attributed to the formation of hydrogen bonds between the -OH, $-NH_2$, -SH, and -COOH groups present on the surface of the CDs with the acrylate group of the PMMA-g-NR latex. This is in turn, facilitated effective interfacial interactions between the CDs and the PMMA-g-NR latex. This finding features the potential of CDs as an efficient nanofiller for improving the physico-mechanical properties of the PMMA-g-NR latex.





Keywords: Bacterial cellulose, Carbon dots, PMMA-g-NR latex, Nanocomposite.

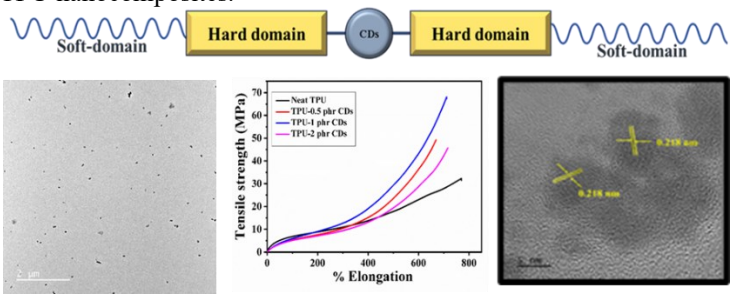
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Covalent embedding of carbon dots onto the main chain of thermoplastic polyurethane via in-situ polymerization for enhanced physico-mechanical properties

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In this study, carbon dots (CDs) were synthesized via a cost-effective solvothermal method [1] employing polytetramethylene ether glycol-1000 and cysteamine hydrochloride, enabling surface functionalization with hydroxyl (–OH), amino (–NH_2), and thiol (–SH) groups. Powder X-ray diffraction (PXRD) analysis confirmed a multilayered framework with partial graphitization and distinct graphitic features. In line with this, high-resolution transmission electron microscopy (HRTEM) revealed spherical CDs with an average diameter of ~5 nm, exhibiting clear lattice fringes embedded within an amorphous, low-crystallinity graphitic matrix (Figure 1 and inset of Figure 1) [2,3]. The resulting CDs were subsequently incorporated into the thermoplastic polyurethane (TPU) matrix via in-situ polymerization, facilitating uniform dispersion and strong interfacial interaction within the polymer network. Introducing CDs onto the main chain of the TPU, along with the soft and hard segments, resulted in an outstanding enhancement in the overall physico-mechanical properties of the TPU nanocomposites. For example, the tensile strength of the TPU nanocomposite containing 1 phr of CDs (TPU-1 phr CDs) increased to ~68 MPa, almost a 112% increment compared to neat TPU (~32 MPa). In addition, at room temperature (25 °C), the storage modulus of the TPU–1phr CDs nanocomposite exhibited a noticeable increase relative to that of neat TPU. Atomic force microscopy (AFM) analysis revealed that the CDs were preferentially in-situ polymerized within the hard segments of the TPU matrix (scheme 1), which in turn led to an outstanding improvement in the overall physico-mechanical properties of the TPU nanocomposites.



Keywords: TPU; Carbon dots; In-situ polymerization.

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Bioactive Zein–FHSA composite films for stimulant delivery

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Our study presents the design and development of a multifunctional bioactive film to address the growing demand for advanced wound healing materials and transdermal drug delivery systems. The film formulation integrates the hydrophilic and biocompatible properties of functionalized human serum albumin (FHSA) with the mechanical stability and structural support offered by zein, a hydrophobic protein derived corn. Functionalization of HSA enhanced its hydrophilicity, allowing improved interaction with water-based environments, while zein contributes to the overall mechanical integrity of the film matrix. Films of FHSA and zein at 25:75 weight ratio were prepared in formic acid by solution cast method. Additionally, graphene oxide (GO) was incorporated at 0.5% w/w to improve mechanical strength and to introduce antimicrobial activity. Vitamin E, a well-known antioxidant and bioactive compound was chosen as a model drug, 20% v/v of the drug was loaded to demonstrate controlled drug release as a function of time. The films were characterized by Fourier-transform infrared spectroscopy (FTIR), field emission scanning electron microscopy (FE-SEM), thermogravimetric analysis (TGA), and swelling studies. The surface morphology studies showed uniform distribution of GO, and the film was porous and favored moisture retention. Notably, films rich in FHSA demonstrated enhanced swelling capacity, a desirable feature for maintaining hydration in wound environments. This work introduced a multifunctional film matrix that integrates structural integrity, antimicrobial activity, and sustained bioactive release, offering strong potential for wound dressing and transdermal therapeutic applications.

Keywords: Zein, functionalized HSA, graphene oxide, Vitamin E, composite films, controlled release, wound healing.

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Microgel@ZnO/Cu NiO Catalyst for Instant Degradation of Hazardous Dyes and Organic Pollutants

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This study explores the development and application of a novel Microgel@ZnO/NiO (Cd-ASVN@ZnO/NiO) nanocomposite as an efficient photocatalyst for the degradation of harmful water pollutants such as Methylene Blue (MB) and para-Dimethyl Amino Benzaldehyde (DMAB). Microgels were synthesized via free-radical emulsion polymerization, employing NHMA as a cross-linker, with varying concentrations to produce three distinct microgel formulations. The integration of ZnO/NiO nanoparticles into microgels was achieved through a hydrothermal process, significantly enhancing their catalytic capabilities. The column method was employed for the adsorption of the respective dyes. The maximum removal efficiencies of the multiple dyes were found to be 98 % for MB, 92 % for CR and 82.6 % for DMAB dye at 0.5 ml/min of the flow rate. Comprehensive characterization was conducted using advanced analytical techniques including XRD, FT-IR, TGA, SEM, and TEM. The photocatalytic performance of the synthesized composites was assessed through UV-Vis spectroscopy, focusing on the impact of cross-linking density, temperature, and pH. With a maximum adsorption capacity of 520 mg/g for MB dye, 490 mg/g for Congo red and 450 for DMAB, respectively, the Langmuir adsorption isotherm best describes the adsorption data. Notably, microgels with higher cross-linker content demonstrated improved degradation efficiency under natural sunlight. Among the composites, Cd-ASVN-3@ZnO/NiO exhibited the highest degradation performance against MB dye, indicating the material's strong potential for eco-friendly and cost-effective wastewater treatment applications.

Keywords: Core-Shell Microgel; Catalysis; Emulsion Polymerization; ZnO/NiO NPs; Wastewater Treatment.

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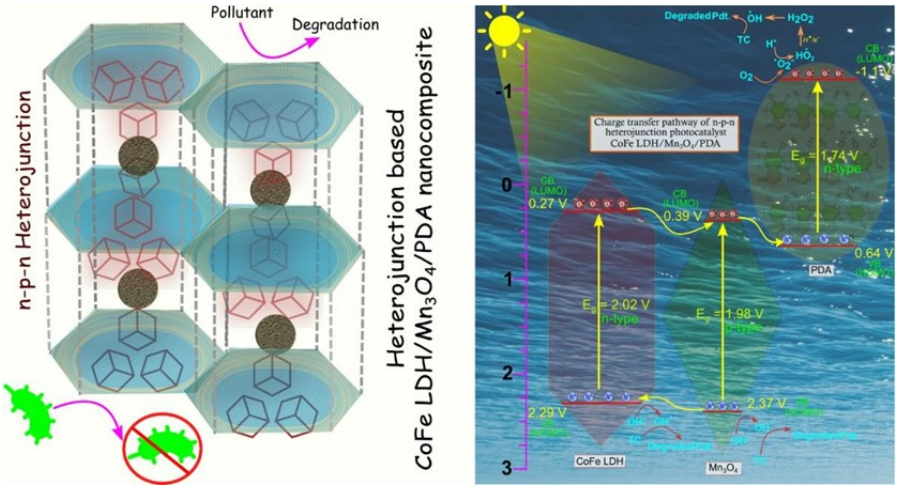
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PDA Integrated CoFe LDH/Mn_3O_4: An n-p-n Heterojunction Based Polymeric Nanocomposite Towards Sunlight Driven Sustainable Degradation of Tetracycline

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Developing efficient multivalent metal semiconductor p-n heterojunctions for superior charge separation remains challenging. This study creates an n-p-n heterojunction by combining n-type CoFe LDH nanosheets with p-type Mn_3O_4 nanocubes, then integrating them with n-type polydopamine (PDA) nanospheres via low-temperature (25 °C) in-situ polymerization. The resulting CoFe LDH/Mn_3O_4/PDA ternary composite achieved 96.3% tetracycline degradation in 90 min. This enhanced performance stems from synergistic interfacial charge dynamics, where electrons channel from LDH through Mn_3O_4 to the conjugated network of PDA, drastically reducing recombination. This was confirmed via XPS, PL, TCSPC, EIS, and photocurrent studies. The composite also exhibits high surface area and strong interfacial interactions, as shown by BET, TEM, and HR-TEM. It also demonstrated potent antibacterial activity against B. *pumilus* and E. *coli*, highlighting its promise for water remediation.



Keywords: heterojunction, semiconductor, polymeric nanocomposite, photocatalyst, sunlight driven.

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Alkaline Anion Exchange Membranes from Polymer Blends

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Alkaline Anion exchange membrane (AAEM) is crucial component for electrochemical energy conversion devices owing to their low fuel crossover, cost-effectiveness, and the ability to operate under alkaline conditions, which enables the use of non-precious metal catalysts. However, achieving a balance between mechanical robustness, chemical stability and high hydroxide conductivity remains a significant challenge. Polymer blending is an effective strategy to tailor membrane properties by combining the complementary advantages of different polymers. In this work, poly(butylated pyridine-bridged oxy-polybenzimidazole)(Py-OPBI) was selected as a primary matrix due to its excellent mechanical strength superior thermal and chemical durability. To further enhance ion-transport properties, Py-OPBI was blended with poly (vinyl-1,2,4-triazolium) (PVT), a polymer with intrinsic cationic sites that facilitates hydroxide conductivity. The resulting Py-OPBI/PVT blend membranes with various compositions (90/10, 80/20,70/30) exhibited significantly improved water uptake and swollen ratio, which contributed to enhanced hydroxide ion mobility. As a result, the optimised blend achieved a high ionic conductivity of 162 mS/cm by (90/10) composition, integrating the structural benefits of Py-OPBI with the high hydroxide conductivity imparted by PVT, offering a balanced platform for advanced AAEM application.

Keywords*:* alkaline anion exchange membrane, miscible blend, water electrolysis, hydroxide ionic conductivity, alkaline stability.

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Hybrid filler-modified polymer-based nanocomposite membranes for water treatment

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A simple and highly facile method for preparing PAN based ultrafiltration membrane using dual filler approach[1] is described. Two fillers of different morphologies were strategically chosen so that the spherical particle (silica) stays in between layered clay(kaolin)[2] and thus reinforces the membranes to improve the longevity. Silica nanoparticles were synthesised by Stöber process. Both silica and kaolin were modified by mussel inspired dopamine polymerisation[3]. Composite membrane containing mixture of silica-PDA and kaolin-PDA at different ratios maintaining a total filler content of 1% were compared with those having unmodified kaolin and silica to evaluate changes in its morphology, thermal, mechanical and antifouling properties. Both dopamine coated and uncoated mixture membrane prepared via phase inversion process showed improved water permeability and selectivity for Congo red dye and BSA protein compared to pristine PAN membrane. This work demonstrates a promising approach for enhancing membrane characteristics through strategic filler combination and their modification for water remediation.

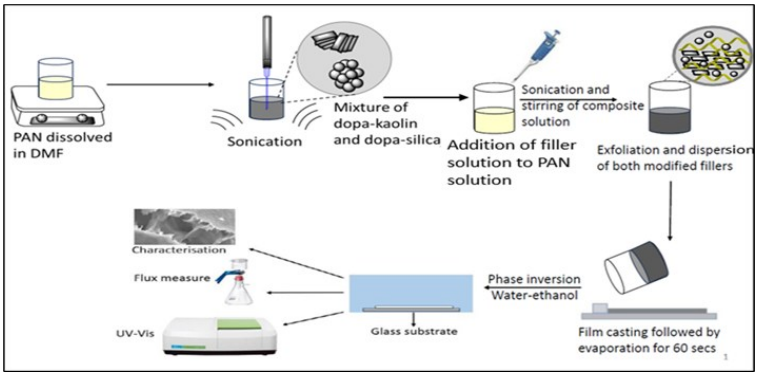


Figure: Schematic Representation of Preparation of Polymeric Nanocomposite Membrane using Modified Hybrid Fillers.

Keywords: Membrane • Nanocomposite • Silica • Clay • Water treatment.

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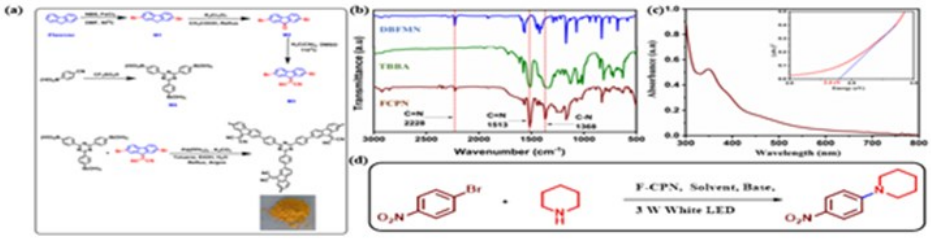
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Visible light-driven C–N cross-coupling reactions catalysed by a conjugated polymer network

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The development of sustainable photocatalysts for carbon-nitrogen (C-N) bond formation is gaining importance in modern organic synthesis.[1] Conjugated polymer networks (CPNs) have emerged as attractive photocatalysts owing to their structural diversity, tunable electronic properties, and high stability.[2] Herein, we report a fluorene-triazine-based CPN (FCPN) synthesized by Suzuki polycondensation [Figure 1(a)] that undergoes in situ Pd doping polymerization, enabling visible-light-driven metallaphotocatalysis. Spectroscopic [Figure 1(b)] and microscopic studies confirmed the polymer's structure, amorphous morphology, and uniform Pd(0) nanocluster (<10nm). The material exhibited a band gap of 2.4 eV [Figure 1(c)], moderate surface area (63.05 m^2 g^{-1}), and favorable HOMO/LUMO levels, ensuring strong charge separation and suppressed exciton recombination. Under white LED irradiation, having intensity 0.05 W cm^{-2} and power 3 watts, the FCPN catalyzed C-N cross-coupling between aryl halides and amines, affording high yields (95-82%) with 5 wt% catalyst loading [Figure 1(d)]. The protocol tolerated aliphatic, aromatic, and heteroaromatic substrates with functional groups such as nitro, cyano, and methoxy. Gram-scale synthesis of 4-(4-nitrophenyl)morpholine, 4-phenylmorpholine, and N-benzylpyridine-2-amine further demonstrated its practical utility. Mechanistic investigation showed that photogenerated charge carriers, in synergy with Pd sites, mediate reductive cleavage of activity, giving a turnover frequency of 1515.46 h^{-1}. This study highlights a simple, recyclable, and energy-efficient polymer photocatalyst for C-N couplings, offering a green alternative to conventional systems.



Figures 1: (a) Total synthetic scheme for the preparation of FCPN, (b) FTIR analysis, (c) UV-vis spectra of FCPN, (d) Schematic illustration of C-N cross-coupling reaction catalyzed by FCPN

Keywords: Conjugated polymer networks, Photocatalysis, C–N cross-coupling, Visible light catalysis, Porous organic polymers.

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Carbon dots -carrageenan nanocomposite functional films with barrier bio coating for real-time monitoring of prawn freshness

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Around one third of the food produced globally is getting wasted between production and consumption, while hunger and malnutrition continue to be major issues in many regions. Along with this, consumers face growing health risks from the consumption of spoiled food. These concerns have intensified with societal development, leading to the emergence of advanced solutions such as intelligent-active packaging in the food packaging industry[1]. Developing such materials with food freshness monitoring and shelf life increments capabilities by using eco-friendly, biodegradable and food safe polymers and indicators can address the afore mentioned challenges as well as non-biodegradability issue associated with traditional petroleum based single use plastics[2].

In the current study, bio compatible urea–dithiosalicylic acid-based carbon dots (UCDs) with aggregation-induced emission property were synthesized through solvothermal reaction and incorporated into carrageenan biopolymer matrix to develop an amine-sensing packaging film. The zein-stearic acid coated composite film (CAR3UCD-C) exhibited good water vapour barrier property (WVTR ≤ 40 g/(m²·day)), high tensile strength (>50 MPa), good thermal stability (up to 200 °C), and complete soil degradability within 35 days. Film showed ammonia sensing capability with a limit of detection of 0.6 µM, antioxidant activity (70% against ABTS radicals), UV-blocking property (~92%) and antibacterial activity against ***E. coli*** and ***S. aureus***. Importantly, the film distinguished prawn freshness through a fluorescence color change (orange to blue) during spoilage, highlighting its potential as an intelligent and biodegradable packaging material for protein-rich foods.

Keywords: Intelligent packaging, Carrageenan, Carbon dots.

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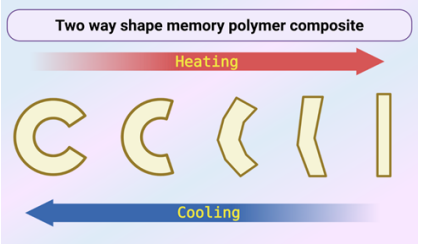
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A Facile Preparation of Segmented Thermoplastic Polyurethane with Octamethyl Polyhedral Oligomeric Silsesquioxane Based Thermoresponsive Programmable Shape Memory Nanocomposites via Mechanically Robust Networks: An Approach Towards Soft Robotic Actuators

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The growing demand for adaptive and programmable materials in soft robotics necessitates the development of polymer systems with combined properties of shape memory functionality, recyclability, and mechanical resilience. Shape memory polymers (SMPs), particularly thermoplastic polyurethane (TPU), have emerged as promising candidates due to their tunable segmented morphology and reprocessability [1]. However, conventional TPU lacks sufficient structural integrity and rapid recovery dynamics for high-performance actuation applications. Herein, we present a facile and scalable approach for preparing thermoresponsive TPU-based nanocomposites incorporating octamethyl polyhedral oligomeric silsesquioxane (OMP-POSS). POSS acts as a multifunctional nano-filler that physically interacts with both soft and hard TPU segments, creating robust hybrid networks without chemical grafting [2,3]. This interaction significantly enhances microphase separation and thermal stability, leading to improved mechanical strength while maintaining elasticity. Morphological characterization using XRD and SEM confirms uniform POSS dispersion, while DSC and DMA analyses indicate tailored glass transition and soft segment melting domains essential for precise actuation control. The developed nanocomposites exhibit exceptional shape memory performance, with shape fixity ratios exceeding 97% and shape recovery ratios above 95% over multiple programming–recovery cycles. Rapid recovery within 3–5 s under mild thermal activation highlights their potential for real-time actuation. Furthermore, the recyclability of TPU is preserved, making the system environmentally sustainable and suitable for large-scale processing. Overall, the synergistic design of TPU and POSS introduces a mechanically robust and thermally responsive material platform capable of delivering adaptive deformation, energy efficiency, and long-term durability. These features make the proposed nanocomposites ideal candidates for soft robotic actuators, deployable structures, and next-generation smart devices.



Figures 1– Two-way shape memory mechanism of TPU/OMP nanocomposites.

Keywords: Thernoresponsive SMPC, Shape fixity, Shape recovery, TPU, Nanocomposites.

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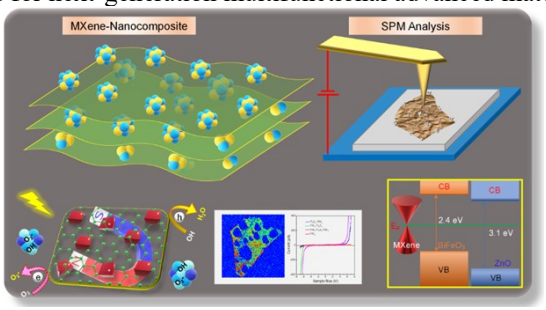
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Microscopic Insights into MXene-Based Nanocomposites for Advanced Material Applications via Scanning Probe Microscopy

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MXene-based nanocomposites have emerged as a promising class of materials due to their unique structural, electronic, and mechanical properties, making them highly suitable for multifunctional advanced applications.[1] A comprehensive understanding of their nanoscale behavior and structure-property relationships is therefore essential for performance optimization.[2] In this study, scanning probe microscopy (SPM) is employed as a powerful tool to provide microscopic insights into the surface morphology, electronic states, and interfacial interactions of Ti_3C_2-MXene-based nanocomposites. By integrating AFM, CAFM, MFM, KPFM, and STM/STS, critical parameters such as surface roughness, conductivity, nanoscale magnetic activity, work function, and electronic band structure are systematically explored. Studies on nanocomposites including Ti_3C_2-TiO_2, Ti_3C_2-$KBi_{0.9}Co_{0.1}Fe_2O_5$, and Ti_3C_2-$BiFeO_3$-ZnO reveal that the introduction of 2D Ti_3C_2 layers generates additional reaction hotspots and enhances charge-transport properties through favorable band alignments at the interface, as evidenced by STM/STS.[3,4,5] Notably, the photocatalytic performance of Ti_3C_2-$KBi_{0.9}Co_{0.1}Fe_2O_5$ is significantly enhanced under simultaneous illumination and external magnetic field, owing to the increased population of spin-polarized photoexcited carriers arising from the synergy of the MXene heterostructure and ferromagnetic spin ordering. These insights demonstrate that SPM serves not only as a high-resolution imaging technique but also as a versatile probe for unveiling functional properties at the nanoscale, thereby highlighting the potential of MXene-based nanocomposites in solar energy harvesting and spintronics for next-generation multifunctional advanced materials.



Figures 1: Schematic representation of MXene-based nanocomposite and its characterization via SPM.

Keywords: MXene, nanocomposites, advanced materials, multifunctional applications.

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Hybrid Nanofilled Chloroprene Elastomer; Preparation and Evaluation of Properties

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Composites of elastomers with hybrid nano-materials can have unique mechanical, thermal, and electrical properties. This study explores the synergistic effects of graphene nanoplatelets (GnP) and multiwalled carbon nanotubes (MWCNT) as a hybrid filler system to enhance the electrical, mechanical, and electromagnetic interference (EMI) shielding properties of a chloroprene (CR) elastomer. Although GnP contributes to structural reinforcement, it does not improve electrical properties due to the higher number of stacked graphene layers. To enhance electrical conductivity, MWCNTs were incorporated within the CR matrix along with GnP, keeping the total filler content constant and systematically varying the filler ratio to determine the threshold hybrid concentration and optimum filler composition. The optimized hybrid filler ratio resulted in a balance of both electrical and mechanical properties. Initially, a composite was prepared using conventional crosslinking. However, to introduce recycling and self-healing properties, a dual dynamic crosslinking approach based on covalent disulfide metathesis and non-covalent ionic interactions was introduced. Additionally, a comparative analysis of crucial properties was studied for both crosslinking systems.

Keywords: Elastomer, Carbon 1D/2D materials, Electrical properties, Mechanical properties, Dynamic crosslinking

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Performance of Gas Separation Using Two-Dimensional Material (h-BN)/Polyimide (PI) Based Mixed-Matrix Membranes

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High aspect ratios and effective spatial usage make two-dimensional (2D) materials attractive options for fillers in the creation of mixed matrix membranes (MMMs).[1–3] Membrane-based methods provide more energy efficiency than traditional gas separation techniques, especially in the purification of natural gas. In order to overcome the performance constraints of conventional polymer membranes, a novel kind of MMM was created. In this work, polyimide (PI) and hexagonal boron nitride (h-BN), a 2D material, were mixed to create a functional filler (h-BN).[1–3] After embedding this filler into the PI matrix, a magnetic field was used to orient the h-BN inside the membrane, improving its capacity to separate CO_2 from CH_4. We examined two h-BN loading levels: 2 and 4 wt%. A CO_2 permeability and a CO_2/CH_4 selectivity of 36 were shown by the MMM with 4 weight percent filler, suggesting that the inclusion of submicron-sized fillers increased separation efficiency. SEM (scanning electron microscopy) verified that the h-BN nanosheets were evenly distributed throughout the PA matrix. The performance of mixed matrix membranes can be enhanced and gas separation applications advanced with the help of this study.

Keywords: Poly(imide), Gas permeability, hexagonal boron nitride, Mixed-matrix membranes.

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High Gas Barrier Films Using LDH Suspensions for Biopolymer-Based Packaging Solutions

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Biopolymers are the emerging alternatives for the synthesis of packaging materials. To impart better gas barrier properties to biopolymers films, cationic clays like Layered double hydroxides can be used. LDHs are metal hydroxide nanosheets. They are highly impermeable to gas by creating tortuous pathways in the matrix they are embedded in [1]. But layered double hydroxides are naturally hydrophilic and can allow water to permeate easily, leading to absorption and swelling by the biopolymer [2]. LDH can also be intercalated with anionic molecules to enhance other surface properties such as hydrophobicity and optical properties [3]. Intercalation of fatty acids into LDH nanosheets will make them hydrophobic and reduce the permeability of water in addition to gas barrier properties, which has been reported in Mg-alloys [2]. Layered double hydroxides are a promising material to improve the barrier properties, along with the hydrophobicity of packaging materials. They can be used in combination with biopolymers to develop scalable, non-toxic, biodegradable packaging solutions [3]. High aspect ratio nanosheets of Mg-Al LDH were synthesized, and their morphological and chemical properties were studied. The synthesis method was optimized, and the LDH was further intercalated with fatty acids like lauric acid and myristic acid to render them hydrophobic. The intercalated organo-LDH was used as a composite with biopolymer films to improve their barrier properties.

Figure 1. Structure of Layered double hydroxides.

Keywords: Layered double hydroxides, tortuous pathway, coating, biopolymer.

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Development and Composting Performance of PHA-Based Biopolymer Blends for Sustainable Packaging Applications

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The growing environmental impact of petroleum-based plastics has intensified the need for sustainable and biodegradable materials. Polyhydroxyalkanoates (PHAs), a family of microbial polyesters, are considered a potential alternative due to their complete biodegradability and biocompatibility [1]. However, their brittleness and limited thermal processability hinder their widespread application [2]. To overcome these limitations, this study explores the formulation and characterization of PHA-based biopolymer blends with various biodegradable polymers such as poly(lactic acid) (PLA), polycaprolactone (PCL), poly(butylene adipate-co-terephthalate) (PBAT), and poly(butylene succinate) (PBS). Melt blending was carried out in a twin-screw extruder at optimized temperature profiles and screw speeds. The mechanical performance (tensile strength, elongation at break) and thermal properties (DSC, TGA) were evaluated to determine the effect of blending ratios. Morphological analysis via SEM and interfacial interactions analyzed through FTIR revealed partial miscibility and enhanced interfacial adhesion, particularly for PHA/PBAT and PHA/PBS systems [3,4]. Controlled composting studies were performed as per ISO 14855 and ASTM D5338 standards to assess biodegradation behavior, showing that PHA/PBAT and PHA/PBS blends exhibit superior flexibility and balanced biodegradation rates under composting conditions [5]. The results demonstrate that strategic blending of PHA with compatible biodegradable polymers can significantly improve toughness and processability without compromising compostability, providing a sustainable alternative for packaging and agricultural film applications.

Keywords: PHA, Biopolymer Blends, Composting, PBAT, PBS.

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Effect of Polymer Chain Length, pH, and Temperature on the Preparation of Polymer-Gold Nanoconjugates and Their Catalytic Performance

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Gold nanoparticles (GNPs) are efficient catalysts owing to their large surface area and unique crystal facets and they tend to aggregate due to high surface energy results in the decrease of catalytic efficiency[1]. Polymer conjugation offers an effective strategy for nanoparticle stabilization[2]. In this study, pH- and thermoresponsive block copolymers, ***poly(N-vinylpyrrolidone)-block-poly(dimethylaminoethyl methacrylate)*** (PNVP-b-PDMAEMA), were synthesized by RAFT polymerization and employed to prepare stable GNPs. The polymer chain length, pH, and temperature significantly influenced nanoparticle morphology and catalytic activity. Interestingly, GNPs could be synthesized without external reducing agents at higher pH values due to polymer-mediated reduction, while acidic conditions required an additional reductant[3,4]. The catalytic activity was assessed through the reduction of 4-nitrophenol, showing enhanced performance at low pH because of favorable ionic interactions between polymer and reactants[5]. These dual-responsive polymer–gold nanoconjugates exhibited non-Arrhenius-type temperature dependence and enabled easy catalyst recovery due to hydrophobic phase transitions, highlighting their promise for tunable and recyclable catalytic systems.

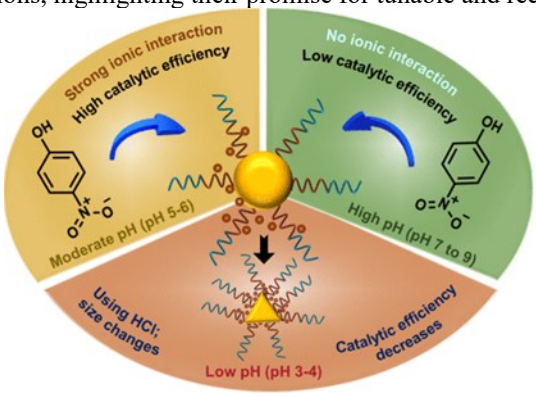


Figure: Effect of pH on Catalysis of Nitrophenol Reduction.

Keywords: Gold nanoparticles; Smart polymers; PNVP-b-PDMAEMA; pH-responsive catalysis; Nanoconjugates.

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Optimization of silane-functionalized cerium oxide and LDH nanoclay for enhanced weather resistance and gas barrier properties of TPU nanocomposite films

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Thermoplastic polyurethane (TPU) elastomer exhibits excellent flexibility, chemical resistance, toughness, and strength, making it suitable for various applications such as inflatables, marine rafts, gas and fuel storage purposes, etc. However, the weather resistance and gas-barrier properties of the TPU polymer are inferior. In this work, cerium oxide (CeO_2), an excellent inorganic UV absorber, and LDH nanoclay have been employed for enhancing the weather-resistance and gas barrier properties of TPU. APTMS silane-modified cerium oxide (CeO_2) nanoparticles were incorporated within the TPU matrix. After that, TPU/ m-CeO_2 nanocomposite films were prepared using the solution casting method at various loadings (3, 5, and 7 wt%) and optimized for weather-resistance performance. In addition, TPU/LDH nanocomposite films (1, 3, and 5 wt%) were also prepared to enhance the gas barrier property of TPU. The developed nanocomposite films were exposed to artificial weathering for 300 h, and the change in chemical structure was characterized using FTIR. The mechanical strength of films was also investigated, and it was observed that the TPU/ m-CeO_2 nanocomposite film at 5 wt% shows higher strength. The ultraviolet protection factor (UPF) of unexposed and exposed nanocomposite films was also evaluated, and nanocomposite films exhibited higher UPF mean values as compared to the neat TPU film. Moreover, TPU/LDH films with 3 wt% loading exhibit better helium gas barrier performance. Thus, modified CeO_2 nanoparticles and LDH nanoclay significantly improve the weather resistance and gas barrier properties of TPU polymer, respectively.

Keywords: Thermoplastic polyurethane, Cerium oxide nanoparticles, LDH nanoclay, UV-resistance property, Gas barrier property.

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Tailoring $ZnSnO_3$ Nanostructures for Gas Barrier and Antibacterial Properties of Thermoplastic Polyurethane Nanocomposites: Role of Morpho-structural Parameters and Plasma-induced Nanotexturing

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Thermoplastic polyurethane (TPU) nanocomposites are transforming the healthcare sector by providing safer, more efficient, and more durable solutions for diverse medical applications, owing to their distinctive attributes of biocompatibility, flexibility, and durability [1-2]. Zinc stannate is a promising antibacterial agent [3]. This study investigates the antibacterial activity of zinc stannate nanostructures in biomedical-grade TPU. Six weight % of these nano fillers were incorporated into TPU using the solvent casting method. TPU films were nanotextured with a solvent-free, sustainable, and efficient plasma technique to improve surface characteristics and the interfacial area of integrated zinc stannate with bacteria. The water contact angle of untreated TPU, initially at 91° (hydrophobic), has been reduced to 45° (hydrophilic) after an optimized treatment duration of 180 seconds. Surface TPU etching and a minor elevation in surface roughness were noted. XPS study showed a reduction in carbon content and a significant increase in oxygen content on the TPU surface, resulting from the incorporation of various oxygen-containing functional groups during plasma treatment. Films were assessed for antibacterial activity to study the influence of differing shapes, aspect ratios, and crystal phases of zinc stannate. A bacterial effectiveness of 87-92% was achieved against both *E. coli* and *S. aureus* bacterial strains. Observations have been corroborated by bacterial adherence tests. Zinc stannate nanorods offer superior UV-blocking properties, with an 81% substantial enhancement in UPF mean value and 33% and 38% improvements in gas barrier properties against helium and oxygen, respectively. TGA indicated minimal thermal degradation in TPU/zinc stannate nanocomposite films compared to pristine TPU films. The underlying mechanisms were also discussed. Therefore, novel zinc stannate-based TPU nanocomposites significantly enhance antibacterial efficacy in combating bacterial infections.

Keywords: Antibacterial, Zinc stannate, Thermoplastic, Nanocomposites.

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Silk–Gelatin Hybrid Hydrogel: A Multifunctional Platform for Enhanced RNA Stability and Controlled Delivery

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Silk fibroin (SF), a natural protein polymer, is increasingly recognized as a next-generation biomaterial for life science applications due to its remarkable mechanical strength, structural tunability, and biological compatibility. In this study, we exploit the intrinsic polymeric versatility of SF to develop a silk-based hybrid hydrogel system for RNA stabilization and controlled release. The designed hydrogel integrates SF with positively charged tyramine-modified gelatin (Gel–TA) to create a polymeric environment that enhances RNA binding, reduces enzymatic degradation, and enables sustainable delivery. Whole-cell RNA was encapsulated within the SF–Gel matrix to assess the polymer–RNA interaction, structural adaptation, and stability. Spectroscopic and microscopic analyses—including FTIR, Raman, and AFM—revealed that SF undergoes significant secondary conformational transitions upon RNA incorporation, characterized by enhanced β-sheet content and reduced α-helical structures, imparting superior molecular rigidity and protection. Zeta potential measurements and agarose electrophoresis confirmed strong electrostatic and hydrogen-bonding interactions between the SF polymer backbone and RNA molecules. Molecular modeling further established SF as the most interactive polymer among collagen and chitosan, supported by lower RMSD values and higher hydrogen bond formation with both rRNA and mRNA species. The SF–Gel–TA composite exhibited controlled RNA release kinetics and effective RNase resistance, underscoring the role of SF as a functional polymer matrix that combines structural stability with biological responsiveness. The tunable polymeric properties of SF—particularly its β-sheet crystallinity and amphiphilic domain organization—enable a delicate balance between rigidity and diffusivity, making it ideal for nucleic acid therapeutics. This polymer-centric platform demonstrates how silk-based biomaterials bridge molecular stabilization and therapeutic delivery, aligning with the emerging paradigm of ***biofunctional polymers in life sciences***. The study provides a mechanistic understanding of SF–RNA molecular interfacing and opens avenues for polymer-driven RNA therapeutics, tissue engineering, and regenerative medicine.

Keywords: Silk fibroin, Functional polymer, RNA delivery, Hybrid hydrogel, Biopolymer–RNA interaction.

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Sulfonated Fe-MOF–Polytriazole Hybrid Membranes with Enhanced Proton Conductivity: Structure–Property Relationships and Application Potential

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Indian Instititue of Technology, Kharagpur, India.

Proton exchange membranes (PEMs) are critical components in fuel cells and other electrochemical energy devices, where they function as ion-conducting barriers separating electrodes while facilitating proton transport. The performance of PEMs depends on achieving high proton conductivity, excellent oxidative stability, controlled water uptake, and robust mechanical properties.

In this work, we report the design and fabrication of advanced hybrid membranes based on sulfonated polytriazole (PTSF) matrices incorporating sulfonated iron-based metal–organic frameworks (Fe-MOFs). The Fe-MOF precursor was synthesized via solvothermal reaction of $FeCl_3 \cdot 6H_2O$ with 2-aminoterephthalic acid, forming Fe-MIL-53-NH_2, which was subsequently post-functionalized through ring-opening sulfonation using 1,3-propane sultone. This sulfonated Fe-MOF (Fe-S MOF) introduces abundant –SO_3H groups, enhancing hydrophilicity and providing potential proton-conducting sites.

The Fe-S MOF was homogeneously incorporated into the sulfonated polytriazole matrix via a solution blending method to prepare free-standing, flexible membranes with varying Fe-S MOF loadings (3–9 wt%). Detailed characterization confirmed successful synthesis and integration of the hybrid membranes. ATR-FTIR and XRD analyses verified chemical modifications, while SEM, AFM, and TEM imaging revealed uniform MOF dispersion and well-separated phase morphologies within the polymer matrix.

Thermal and mechanical testing demonstrated that the hybrid membranes retained high oxidative stability and good dimensional stability. The inclusion of sulfonated Fe-MOF improved water uptake (up to 38% at 80 °C) while maintaining controlled swelling ratios (7–15% at 80 °C). Importantly, proton conductivity was significantly enhanced, with maximum values reaching approximately 80 mS cm^{-1} at 80 °C, surpassing the pristine PTSF membrane. The improved proton transport can be attributed to the formation of interconnected ionic channels facilitated by the uniformly dispersed MOF nanoparticles and their hydrophilic domains.

These results demonstrate that the sulfonated Fe-MOF/PTS hybrid membranes offer an effective strategy for designing next-generation PEM materials. By balancing conductivity, stability, and processability, these materials show strong potential for use in fuel cells and other electrochemical devices requiring efficient ion-conducting membranes.

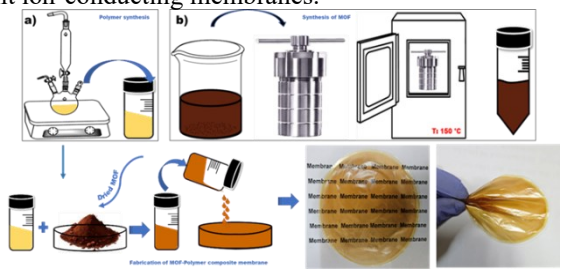


Figure 1 – Fabrication of MOF-Polymer composite membrane.

Keywords: Sulfonated polytriazole, Metal–organic framework, Proton exchange membrane, Hybrid composite, Fuel cell applications.

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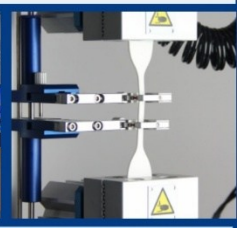
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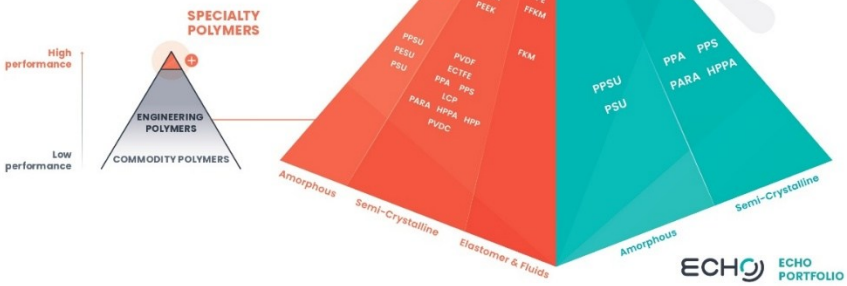
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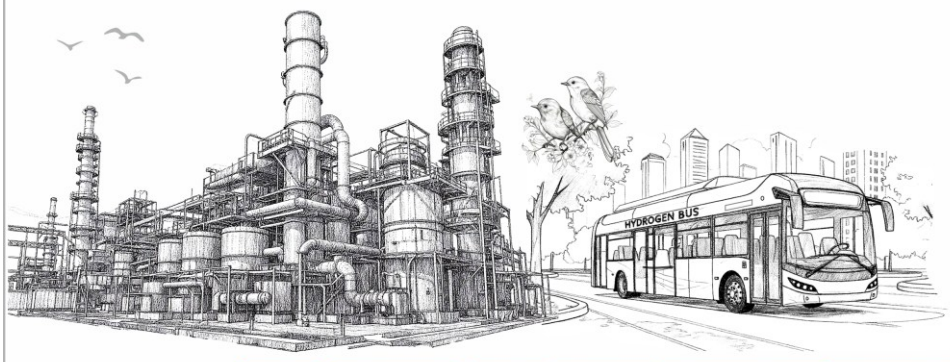


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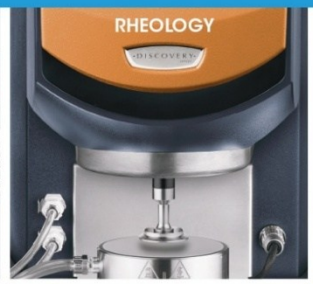


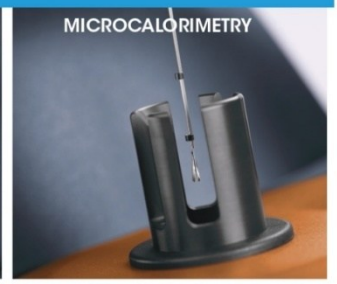
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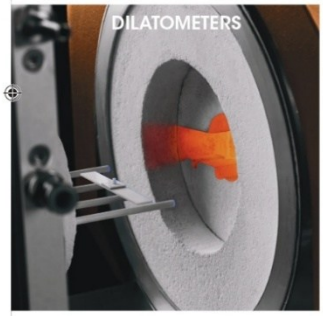

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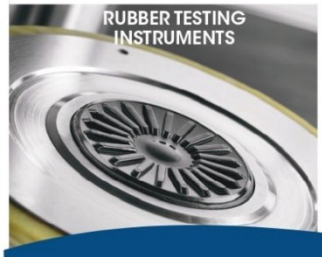






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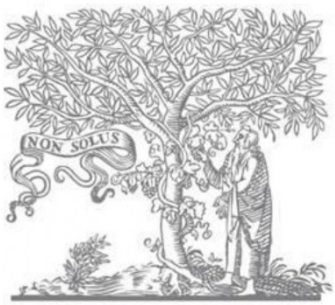
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The Society was established as Professional Society in March 1979 under the guidance and leadership of Prof. H. Kothandaraman and had its office in Department of Polymer Science, Anna University, Madras. Dr. R.A. Mashelkar, ex-director general, CSIR was elected as the president of this society in 1991 during the Symposium Polymers '91. In order to establish a vibrant national-level professional society to help to shape national policies in the area of polymeric materials, a decision was taken in February 1995 to unite all existing polymer-related societies in India under one banner, The Society for Polymer Science, India. Prof. I. K. Varma was elected as the president of the society in 1995. A sub-committee under the chairpersonship of Prof. I. K. Varma was constituted to look into the rules, regulations and bye laws of the society. The revised Memorandum of association and rules were approved in the general body meeting held at MACRO'95 and it was decided to move the headquarter from Madras to Pune under the leadership of Dr. S. Sivaram for administrative convenience. The Society functions through ten regional chapters, namely at Bangalore, Calicut, Chennai, Delhi,, Kharagpur, Kolkata, Pune and Thiruvananthapuram. Pune is the Headquarter of the Society.

Indian Institute of Technology Kharagpur

The Indian Institute of Technology Kharagpur (IITKGP) is a public institute of technology, research university, and autonomous institute established by the Government of India in Kharagpur, West Bengal. Founded in 1951, the institute is the first of the IITs to be established and is recognized as an institute of national importance. In 2019 it was awarded the status of Institute of eminence by the government of India. The motto of IIT Kharagpur is "योगः कर्मसु कौशलम्". This literally translates to "Excellence in action is Yoga", essentially implying that doing your work well is (true) yoga. This can be traced to Sri Krishna's discourse with Arjuna in the Bhagavad Gita. The quote, in the larger context of the Gita, urges man to acquire equanimity because a mind of equanimity allows a man to shed distracting thoughts of the effects of his deeds and concentrate on the task before him. Equanimity is the source of perfection in Karmic endeavors that leads to Salvation. The institute was initially established to train engineers after India attained independence in 1947. However, over the years, the institute's academic capabilities diversified with offerings in management, law, architecture, humanities, medicine, etc. The institute has an 8.7-square-kilometre (2,100-acre) campus and has about 22,000 residents.

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