The 36th International Symposium for Polymer Analysis and Characterization (ISPAC) will be held in Singapore at Nanyang Technological University (NTU) from June 23 to 27, 2025.

The conference features a range of engaging symposia and distinguished speakers, offering an excellent platform to present your research and connect with peers in the field. Preceding the three-day main conference (June 25 – 27), there will also be two full days of short courses (June 23 – 24) designed to support research students, early-career researchers and new technical professionals.

Short courses**:**

- Electron microscopy for soft materials
- Rheology- application in materials processing and formulation
- Light scattering methods for polymers
- Mass spectrometry as a detector in polymer chromatography – scopes and limitations

Scientific session topics**:**

- Challenges and opportunities in polymer characterization through traditional and AI approaches
- Advancing polymers for a sustainable future (including environmental and green manufacturing)
- Polymer for personal care, healthcare and food applications
- Polymer and composites for industrial applications
- Novel polymers in emerging applications

Join us at ISPAC 2025 to connect with leading experts and the international polymer community. We look forward to your contributions and participation.

Monday, 23 June 2025
Short Course Day 1
Venue: Lecture Theatre 3, Nanyang Technological University

09.00 - 09.30	Registration
	Electron Microscopy for Soft Materials & Beam Sensitive Materials:
09.30 – 11.00	Electron Microscopy for Soft Materials *Professor Hiroshi Jinnai* *Tohoku University, Japan*
11.00 – 11.20	Tea break
	Rheology:
11.20 - 12.50	Rheology- Application in Materials Processing and Formulation *Professor Michael Tam* *University of Waterloo, Canada*
12.50 - 14.00	Lunch
14.00 - 16.00	**Electron Microscopy for Soft Materials & Beam Sensitive Materials** **Workshop Session** *Professor Hiroshi Jinnai (Tohoku University)* *Dr Tetsuo Oikawa (JEOL Asia)* *FACTS*
	Rheology for Polymers **Workshop Session** *Professor Michael Tam (University of Waterloo)* *Professor Terry Steele (Nanyang Technological University)* *MSE Maker Space*
16.00	- End -

Tuesday, 24 June 2025
Short Course Day 2
Venue: Lecture Theatre 3, Nanyang Technological University

	Multimodal Characterisation:	
09.30 – 11.00	Mass Spectrometry as a Detector in Polymer Chromatography - Scopes and Limitations *Professor Clemens Schwarzinger* *Johannes Kepler University Linz, Austria*	
11.00 – 11.20	Tea break	
	Scattering Methods for Polymers:	
11.20 - 12.50	Light Scattering Methods for Polymers *Professor Sheng Dai* *University of Leeds, United Kingdom*	
12.50 - 14.00	Lunch	
14.00 - 16.00	**Electron Microscopy for Soft Materials & Beam Sensitive Materials** **Workshop Session** *Professor Hiroshi Jinnai (Tohoku University)* *Dr Tetsuo Oikawa (JEOL Asia)* *FACTS*	**Rheology for Polymers** **Workshop Session** *Professor Michael Tam (University of Waterloo)* *Professor Terry Steele (Nanyang Technological University)* *MSE Maker Space*
16.00	- End -	

Wednesday, 25 June 2025
Conference Day 1
Venue: Auditorium (AUD302), Executive Centre at NTU@one-north

08.30 – 09.00	Registration with Light Refreshment
09.00 - 09.10	Opening of ISPAC 2025
	Novel Polymers in Emerging Applications (Chaired by Professor Hiroshi Jinnai)
09.10 – 09.40	Keynote Talk Monitoring and Characterization of Stability of Biologic Medicines *Professor Wayne F. Reed* *Tulane University, United States of America*
09.40 – 10.10	Keynote Talk Dynamic Covalent Bond-Based Architectures and Their Characterization *Professor Nikos Hadjichristidis* *King Abdullah University of Science and Technology, Saudi Arabia*
10.10 - 10.40	Keynote Talk Polymers in Emerging Healthcare and Energy Transition Applications *Professor Sheng Dai* *University of Leeds, United Kingdom*
10.40 - 11.10	Panel Discussion
11.10 - 11.30	Tea break

Parallel Sessions	Novel Polymers in Emerging Applications *Venue: Auditorium (AUD302)* *(Chaired by Clemens Schwarzinger & Boon Peng Chang)*	Advancing Polymers for a Sustainable Future *Venue: Lecture Theatre (LT301)* *(Chaired by Dalton Chor Yong Tay & Jun Kit Wang)*
11.30 - 11.55	Special Invited Talk Polymer Crosslinkers for On-Demand Production of Strong, Recyclable Thermoset Composites, Patterned Quantum-Dot Displays, and Low-Loss Dielectric Materials *Professor Jeremy Wulff* *University of Victoria, Canada*	Special Invited Talk Harnessing Dynamically Separated Polymer Nanostructures for Advanced Energy Applications *Professor Michele Mauri* *University of Milano-Bicocca, Italy*
11.55 - 12.10	Contributed Talk 1 Macromolecular Engineering of Ionogels with Multifaceted Applications *Xueling Feng* *Donghua University, China*	Contributed Talk 1 Formation of Disorder Crystals in Biobased Poly(Butylene Succinate), Their Structure and Reorganization as Studied by Fast Scanning Chip Calorimetry and X-ray Techniques René Androsch *Martin Luther University Halle-Wittenberg, Germany*

12.10 - 12.25	Contributed Talk 2 Self-Healing Decuple Hydrogen-Bonded PDMS Elastomers for Triboelectric and Mechanoluminescent Applications *Anatoli Kurkin* *Nanyang Technological University, Singapore*	Contributed Talk 2 Sustainable Non-isocyanate Polyurethane (NIPU): Functionality and Applications *Satyasankar Jana* *Institute of Sustainability for Chemicals, Energy and Environment, Singapore*
12.25 - 12.40	Contributed Talk 3 Advanced Triphenylamine-based Polymers as Multifunctional Electrodes Materials for Next-Generation Organic Lithium-Ion Batteries *Febri Baskoro* *Bandung Institute of Technology, Indonesia*	Contributed Talk 3 Self-Healable and Reprocessable Fluorinated Polyurethane Vitrimers *Yew Jin Ong* *Nanyang Technological University, Singapore*

12.40 – 14.00 Networking Lunch & Product Gallery (Function Hall)

Advancing Polymers for a Sustainable Future
(Chaired by Professor Yeng Ming Lam)

14.00 - 14.30 Keynote Talk
Mechanochemistry and Aging-based Methods as Novel Tools to Transform Biopolymers into High Value Materials
Professor Audrey Moores
McGill University, Canada

14.30 - 15.00 Keynote Talk
Soft Polymeric Nanostructures - Synthesis, Properties and Applications
Professor Michael Tam
University of Waterloo, Canada

15.00 - 15.30 Keynote Talk
Plastics for Good: New materials from Lignocellulosic Biomass
Professor Harm-Anton Klok
École Polytechnique Fédérale de Lausanne, Switzerland

15.30 - 16.00 Panel Discussion

16.00 - 16.20 Tea break

Parallel Sessions

	Novel Polymers in Emerging Applications *Venue: Auditorium (AUD302)* *(Chaired by Shermin Simin Goh)*	Polymer & Composites for Industrial Applications *Venue: Lecture Theatre (LT301)* *(Chaired by Yee Yan Tay)*
16.20 - 16.35	Contributed Talk 4 3D Deformation of Liquid Crystals Elastomer for Small-Scale Structural Manipulation *Mingchao Zhang* *National University of Singapore, Singapore*	Contributed Talk 1 Role of Poly(styrene-isoprene-styrene) (SIS) Copolymer Macromolecular Design in Flexible Electrothermal Composite Heater performance *Hiruni Dedduwakumara* *Queensland University of Technology, Australia*

16.35 - 16.50	Contributed Talk 5 Investigating the Impact of Lignin as an Organic Polymer in Semiconductor Materials on Charge Density Dynamics Using an LED-Based Sun Simulator in Dye-Sensitized Solar Cells *Gita Rabelsa* *Bandung Institute of Technology, Indonesia*	Contributed Talk 2 Lightweight, Flexible and Sustainable Piezoresistive Foam Sensors for Wearable Electronics and Motion Monitoring *Boon Peng Chang* *Nanyang Technological University, Singapore*
16.50 - 17.05	Contributed Talk 6 Microfluidics-Driven Piezo-Sono-Photocatalysis: An Innovative Approach for Accelerated Water Pollutant Degradation Assisted by PVDF-Transition Metal Sulphide Based Piezocatalysts *Alisha Rohal* *Institute of Nanoscience and Technology, India*	Contributed Talk 3 Wetting Characteristics and Thermal Stability of Polymer-Treated Gas Diffusion Layers for Fuel Cell Applications *Heri Suripto* *Gadjah Mada University, Indonesia*

17.05 - 18.30 Drinks & Bites: Poster Session & Judging Session (Function Hall)

18.30 – 20.00 Speakers' Dinner

20.00 - End -

Thursday, 26 June 2025
Conference Day 2
Venue: Auditorium (AUD302), Executive Centre at NTU@one-north

08.30 – 09.00	Light Refreshment
	Polymers for Personal Care, Healthcare & Food Applications ***(Chaired by Professors Terry Steele (I) & Lay Poh Tan (II))***
09.00 – 09.30	Keynote Talk The Importance of Polymer Characterization in Consumer Products *Dr Ron Swift* *Procter & Gamble, United States of America*
09.30 – 10.00	Keynote Talk Bio-Based Polymer Innovations for Cosmetic Formulations *Professor Reinhold Dauskardt* *Stanford University, United States of America*
10.00 - 10.20	Panel Discussion (I)
10.20 - 10.40	Tea break
10.40 - 11.10	Keynote Talk Biomaterials and Tissue Engineering: Characterisation Challenges and Potential Solutions *Professor Neil Cameron* *Monash University, Australia*
11.10 - 11.40	Keynote Talk Scaffolds for Cultured Fat with Low Cholesterol and Better Lipo-nutritional Properties *Professor Shan Tizhong* *Zhejiang University, People' s Republic of China*
11.40 - 12.00	Panel Discussion (II)
12.00 - 12.10	Break

Parallel Sessions	Advancing Polymers for a Sustainable Future *Venue: Auditorium (AUD302)* *(Chaired by Rui Goncalves)*	Polymer & Composites for Industrial Applications *Venue: Lecture Theatre (LT301)* *(Chaired by Aravind Dasari)*
12.10 - 12.25	Contributed Talk 4 In-Depth Analysis of the Folding Behaviour of Single-Chain Casein Nanoparticles Cross-linked by Microbial Transglutaminase *Joshua Johani* *Leibniz-Institute of Polymer Research Dresden, Germany*	Contributed Talk 4 Loose Chip Form Polyphenylene Sulphide Carbon Fibre Reinforced Composites Processed with Extended Crystallisation Stage *Marcin Debowski* *Singapore Institute of Manufacturing Technology, Singapore*
12.25 - 12.40	Contributed Talk 5 Novel Divinylbenzene-Based Sorbents for Efficient Heavy Metal Removal from	Contributed Talk 5 Voltage Activated Curing of Structural Adhesive

	Wastewater *Yamin Wang* *Nanyang Technological University, Singapore*	*Animesh Ghosh* *Nanyang Technological University, Singapore*
12.40 - 12.55	Contributed Talk 6 Biodegradable Nanoparticle Loaded Bacterial Cellulose Membranes Through Bioengineered Approach for Agricultural Application *Meghana Gattupalli* *Indian Institute of Technology Delhi, India*	Contributed Talk 6 One Pot Synthesis of Ceramic-Reinforced Hydrogel Composites with Bioinspired Microstructures Using Magnetic Assisted Slip Casting *Slocha Sapasakulvanit* *Nanyang Technological University, Singapore*

12.55 – 14.00 Networking Lunch & Product Gallery (Function Hall)

	Polymer & Composites for Industrial Applications *(Chaired by Professor Wayne F. Reed)*
14.00 - 14.30	Keynote Talk "Devilish", Responsive Polymer Surfaces: The Characterization Challenge *Professor G. Julius Vancso* *University of Twente, Netherlands*
14.30 - 15.00	Keynote Talk Slide-Ring Materials for Circular Economy *Professor Kohzo Ito* *University of Tokyo, Japan*
15.00 - 15.30	Keynote Talk Scalability aspects of polymeric materials from the viewpoint of fire protection *Professor Aravind Dasari* *Nanyang Technological University, Singapore*
15.30 - 16.00	Panel Discussion
16.00 - 16.20	Tea break

Parallel Sessions	Polymers for Personal Care, Healthcare & Food Applications *Venue: Auditorium (AUD302)* *(Chaired by Teddy Salim)*	Challenges & Opportunities in Polymer Characterization through Traditional & AI Approaches *Venue: Lecture Theatre (LT301)* *(Chaired by Husen Kang)*
16.20 - 16.35	Contributed Talk 1 How Alcohol Initiator Type and Molecular Weight Influence the Crystallization and Melt Memory of Poly(ε-caprolactone) (PCL) *M. Ali Aboudzadeh* *University of the Basque Country, Spain*	Contributed Talk 1 Automated Pipetting Robot for Proxy High-Throughput Viscometry *Beatrice Soh* *Institute of Materials Research and Engineering, Singapore*
16.35 - 16.50	Contributed Talk 2 Modification of Polyacrylonitrile Yarn for Durable Antibacterial, Anti-Odour and Anti-Mosquito Properties *Vitali Lipik* *Nanyang Technological University, Singapore*	Contributed Talk 2 Advances in AI-Enabled Polymer Characterisation with Hyperspectral Data for Plastic Waste Sorting *Edward Neo* *Singapore Institute of Manufacturing Technology, Singapore*

16.50 - 17.05	Contributed Talk 3 Unravelling the Synergistic Effect of Multiscale Hierarchical Material Architecture for Enhanced Urea Adsorption *Zhihao Yen* *Nanyang Technological University, Singapore*	Contributed Talk 3 Accurate Identification of Micro and Nanoplastic (MNP) with Sub-Micron Infrared Spectroscopic Instrumentation (O-PTIR) *Mike Lo* *Photothermal Spectroscopy Corp, United States*
17.05 - 17.20	Contributed Talk 4 Enhancing the Compatibility Between 3D Printable Hydrogel and Human Skin Through Mechanical and Chemical Composition Characterization *Jaw Wei Qi* *Nanyang Technological University, Singapore*	Contributed Talk 4 Advancing Sustainable Polymer Characterization with AFM-IR: Chemical and Nanomechanical Insights *Yun Chen* *Bruker, Singapore*
17.20 - 17.35	Contributed Talk 5 Antibacterial, Wash-Resistant Coatings Based on Imine-Grafted Catechol Isomers *Konrad Kozlowski* *Nanyang Technological University, Singapore*	Contributed Talk 5 Advancing Materials Research with Cryogenic Focused Ion Beam (FIB)-SEM *Ng Feng Lin* *Carl Zeiss Pte Ltd, Singapore*

17.35 - 20.00 Conference Dinner

20.00 - End -

Friday, 27 June 2025
Conference Day 3
Venue: Auditorium (AUD302), Executive Centre at NTU@one-north

08.30 – 09.00 Light Refreshment

Parallel Sessions	Challenges & Opportunities in Polymer Characterization through Traditional & AI Approaches *Venue: Auditorium (AUD302)* *(Chaired by Tseng Jo-Chi)*	Polymer & Composites for Industrial Applications *Venue: Lecture Theatre (LT301)* *(Chaired by Vivek Arjunan Vasantha)*
09.00 - 09.15	Contributed Talk 6 Sophisticated Approaches for Determining Mechanical Properties in Semicrystalline Polymers *Katalee Jariyavidyanont* *Martin Luther University Halle-Wittenberg, Germany*	Contributed Talk 7 Characterization of Magnetic Induction-Cured Thermoset Resin Composites by the Nano-CT Technique *Tran Quang Dung* *Nanyang Technological University, Singapore*
09.15 - 09.30	Contributed Talk 7 Curvature-Induced Self-Assembly of Molecular Chains in Tetragonal Crystals into 45°-Tilted Long-Range Order *Yan Cao* *South China University of Technology, China*	Contributed Talk 8 A Greener Approach for Physical Separation of Polycotton Textile Waste *Ying Siew Khoo* *Nanyang Technological University, Singapore*
09.30 - 09.45	Contributed Talk 8 From Linear to Multifunctional Building Blocks: How to Challenge the Complex Structural Analysis of Branched Polyesters *Klara Saller* *Johannes Kepler University Linz, Austria*	Contributed Talk 9 Open-Hole Tensile and Compressive Strengths of Double-Double Composites *Andi Haris* *Singapore Institute of Manufacturing Technology, Singapore*
09.45 - 10.00	Contributed Talk 9 Small Angle X-ray and Neutron Scattering Study of Structure and Dynamics in Polymer Gels *Wu Baohu* *Forschungszentrum Jülich, Germany*	Contributed Talk 10 Young's Modulus of Polyamide 11 (PA 11) of Different Semicrystalline Morphology *Mengxue Du* *Martin Luther University Halle-Wittenberg, Germany*

10.00 - 10.20 Tea Break

Challenges & Opportunities in Polymer Characterization through Traditional & AI Approaches (Chaired by Professor G. Julius Vancso)

10.20 - 10.50 Keynote Talk
Novel Separations for Complex Architectures – From Single Chain Nanoparticles to Multichain Assemblies
Professor Albena Lederer
Leibniz Institut für Polymerforschung Dresden, Germany

10.50 – 11.20 Keynote Talk
In-line Model Supported and Data-Driven Optimization of Technical and Functional Polymer Processing
Professor Jens W Andreasen
Technical University of Denmark, Denmark

11.20 – 11.50	Keynote Talk AI/ML in Additive Manufacturing and Polymer Synthesis for New Data and Discovery *Professor Rigoberto Advincula* *University of Tennessee, United States of America*	
11.50 – 12.20	Panel Discussion	
12.20 - 12.35	Award Ceremony/ Invitation to ISPAC 2026	
12.35 - 12.45	Conference Closing	
12.45 – 14.00	Networking Lunch & Product Gallery (Function Hall)	
14.00 - 15.30	Tour of Nanyang Technological University Campus & Facilities	Tour of Institute of Materials Research & Engineering (A*STAR)
15.30	- End -	

Poster Session
Conference Day 1
Venue: Function Hall, Executive Centre at NTU@one-north

P1	Flame Retardant Polymer Barriers for Mitigating Thermal Runaway Propagation of Lithium-Ion Battery *Suchaya Chaiworn* *Nanyang Technological University, Singapore*
P2	Improvement of Antibacterial Activity of Electrospun Gelatin Nanofibers by Grafting of Quaternary Ammonium Groups *Kuo-Yu Chen* *National Yunlin University of Science and Technology, Taiwan*
P3	Structural Evolution of Mesoporous Magnesium Aluminates with Platinum Single Atoms and Nanoclusters for Thermal Hydrogenation Catalysis *Qihang Chen* *Nanyang Technological University, Singapore*
P4	Characterisation of Hydrogel-Laser Interaction upon Laser Ablation *Shi Hui Cheng* *Nanyang Technological University, Singapore*
P5	Synthesis and Characterization on TPU with Varying Biomass Polyol Content *Bohyeon Cho* *Korean Institute of Materials Convergence Technology, South Korea*
P6	Sodium Bicarbonate-Driven Synergy of Acetate and Propionate for Improved Rhodobacter sphaeroides Growth and Polyhydroxyalkanoates Yield *Manmadha Manikanta Doki* *Indian Institute of Technology Kharagpur, India*
P7	Sustainable Epoxy-Amine Resins for High-Performance Applications *William Dyer* *Delft University of Technology, The Netherlands*
P8	Got Water? A Rapid Method for Estimating the Hydraulic Properties of Polymer-Treated Substrates *Sherwin Escayo* *Nanyang Technological University, Singapore*
P9	Low Frequency Raman Spectra of Poly Ether Ketone Ketone (PEKK) *Yusuke Fujishima* *Akita University, Japan*
P10	Images, Insights and Throughput: Using AI and Automation to Drive Workflows on Electron Microscopy *Ronn Goei* *Carl Zeiss Pte Ltd, Singapore*
P11	Advancing Chemical Recycling of Mixed Textile Waste : Challenges in Separation and Characterization *Nupur Gupta* *Nanyang Technological University, Singapore*
P12	Development of Novel Cadmium Adsorbents by Targeted Exploration of Functional Group and Surrogate Templating Effects *Peter Haywood* *Nanyang Technological University, Singapore*

P13	Characterization of Porous Zeolites Using Hydrogen and Oxygen Adsorption with a Particular Focus in Ultra-Micropores *Ruby Hooi* *Micromeritics Corporation, USA*
P14	Carbon Dioxide Capture by Meso and Microporous Adsorbents Loaded with Amines in Dry and Humid Conditions, Investigation with the Breakthrough Analyzer *Ruby Hooi* *Micromeritics Corporation, USA*
P15	Temperature Programmed Surface Reactions with Alcohols and Isopropylamine *Ruby Hooi* *Micromeritics Corporation, USA*
P16	Predictive Modeling and Transfer Learning for Gel Fraction Measurement of GelMA with Additives *Xi Huang* *Nanyang Technological University, Singapore*
P17	Hybrid Benzoxazine Networks: A Molecular Design Approach Using Main-Chain Precursors and POSS *Binting Huang* *National University of Singapore, Singapore*
P18	Development of Adjustable PCLA Based 3D Bioprinting Ink for Controlled Dexamethasone Release *YunGeon Jeong* *Ajou University, South Korea*
P19	Oxidation-Responsive Biodegradable Polymers and Their Applications *Tae Woong Kang* *Ajou University, South Korea*
P20	Study on the Absorption Properties of Crosslinked CMC-based SAP with PEG Addition *Gyu Dong Lee* *Korea Institute of Industrial Technology, South Korea*
P21	Characterising the Effects of Varying pKa on the Gelation Properties of Organogels *Samuel Lee* *Nanyang Technological University, Singapore*
P22	Dynamic Crosslinking of Commodity Thermoplastics to Create Recyclable Thermosets via Perfluorophenyl Nitrene C-H Insertion *Zhi Yuan Lee* *Institute of Materials Research and Engineering, Singapore*
P23	Understanding the Relationship between CO_2 Reduction Reaction (CO_2RR) Performance and Surface Terminations of MXenes is Crucial for Designing Effective Electrocatalysts *Caihong Liang* *Nanyang Technological University, Singapore*
P24	Application of Novel Submicron Infrared (O-PTIR) Spectroscopy Towards Accurate Identification of Polymeric Materials in Microelectronics and Packaging *Michael Lo* *Photothermal Spectroscopy Corp, United States*
P25	Metal-Coordinated Enzyme Nanogels for Biomedical Therapy: From Polymer Design to Functional Validation *Yedong Ma* *National University of Singapore, Singapore*

P26	Material Development of Electrode with Hydrophobic Microcavity for High Efficiency Electrolysis Process *Iskandar Ali Mubarok* *Gadjah Mada University, Indonesia*
P27	Hierarchically Porous Polymers Derived from Evaporation Induced Self Assembly *Wan Ting Ng* *Nanyang Technological University, Singapore*
P28	Impact of Cellulose Derivatives on the Performance of Gastroretentive Floating Tablets Fabricated via Sugar Templating Technique *Pattaraporn Panraksa* *Chiang Mai University, Thailand*
P29	Eco-Engineered Oxidative Pathway to Enable Circularity of Cellulose from Textile Waste *Geok Leng Zoey Seah* *Nanyang Technological University, Singapore*
P30	SPEEK/Sulfonated Chitosan/ Sulfonated Multi-Walled Carbon Nanotubes as a Proton Exchange Membrane for Non-Enzymatic Biofuel Cells *Mythrehi Sekar* *Anna University, India*
P31	FDM 3D Printing of Gastroretentive Drug Delivery System Using Shape-Memory Polymer Blended with Cassava-Derived Natural Fibres *Krit Sengtakdaed* *Chiang Mai University, Thailand*
P32	Carboxymethyl Cellulose-Based Foam Dressing Containing Silver Nanoparticles *Hawon Seo* *Korea Institute of Industrial Technology, South Korea*
P33	Multifunctional Transparent Conductive Flexible Sensor Based on Graphene/Polyaniline/Graphene Sandwich Composite on PDMS Substrate *Surbi Singh* *Suresh Gyan Vihar University, India*
P34	NMR and Optical Characterisation of Transparent Wood Composite for Optical Diffusers Application *Lorenzo Squitieri* *University of Milano-Bicocca, Italy*
P35	Recent Progress and Challenges in Membrane Electrode Assembly Materials for Proton Exchange Membrane Fuel Cells *Heri Suripto* *Gadjah Mada University, Indonesia*
P36	Effect of Plastic Strain on Low-Wavenumber Raman Scattering in Poly Ether Ether Ketone (PEEK) *Yuya Takahashi* *Akita University, Japan*
P37	The Effect of Resins on Kinetics of the Glass Transition of Silica-Filled Styrene–Butadiene Rubber *Maxim Usachev* *Mettler-Toledo Pte Ltd, Singapore*
P38	Sustainable Cellulose Extraction from Plant Waste Using Deep Eutectic Solvents *Lifei Xi* *Nanyang Technological University, Singapore*

P39	Curie Nanoparticles Assisted Polymerization by Magnetic Induction Hyperthermia *Muralidhar Yadav* *Nanyang Technological University, Singapore*
P40	Investigation of the Discrimination between Recycled and Virgin PET Fibers Using MALDI-TOF MS *Yuzo Yamazaki* *Shimadzu Corporation, Japan*
P41	Engineering Morphology and Crystallinity in PVDF-HFP-Based Polymer Electrolyte Nanocomposites for Solid-State Lithium Batteries *Ziyi Zhang* *National University of Singapore, Singapore*
P42	Poly(Ionic Liquid) Heterojunction Analogue of Synaptic Plasticity *Falihah Balqis* *Nanyang Technological University, Singapore*
P43	Scalable Cellulose Fiber Electrodes with Green Nanoparticle-Modified Carbon for Enhanced Ion Storage and Capacitive Deionization *Satish Kumar* *Indian Institute of Technology Guwahati, India*

Novel Polymers in Emerging Applications

Monitoring and Characterization of Stability of Biologic Medicines

Reed, Wayne F
Tulane University
United States of America

Biologic medicines (biologics) are enormously successful in treating many complex diseases and encompass monoclonal antibodies, other therapeutic proteins, lipid nanoparticles, mRNA, vaccines, viral capsids for gene therapy, and more. A ubiquitous issue for all of these is finding formulation conditions under which the medicine remains stable. Instability in formulations can manifest in terms of irreversible aggregation, reversible associations, molar mass degradation, and phase separation. Biologics are generally biomacromolecular or colloidal so that light scattering is exquisitely sensitive to such instability processes. In this work the focus is on a newly developed method for spectroscopic monitoring of biologics undergoing dialysis against electrolytes, buffers, chaotropic agents, and excipients [1]. The method allows monitoring the behavior of biologics as the concentration of any of these agents changes gradually and continuously. Importantly, the reversibility of the instability processes can be assessed by dialyzing solutions back to their initial conditions. Results from this method are complemented by monitoring the kinetics of these processes under fixed solution conditions.

Case studies involving several biologics, as well as non-medicinal macromolecules are presented for selected proteins, RNA, viral capsids, electrically charged polysaccharides, and a synthetic polyelectrolyte. A wide variety of behaviors was found among these as they were dialyzed against i) a simple electrolyte (NaCl) and ii) a chaotropic agent (Guanidine-HCl, or Gd).

A model based on competing intermolecular electrostatic repulsion (E) and attractive H-bond/hydrophobic effects (HP) allowed the widely varying behaviors to be interpreted in terms of E/HP effects.

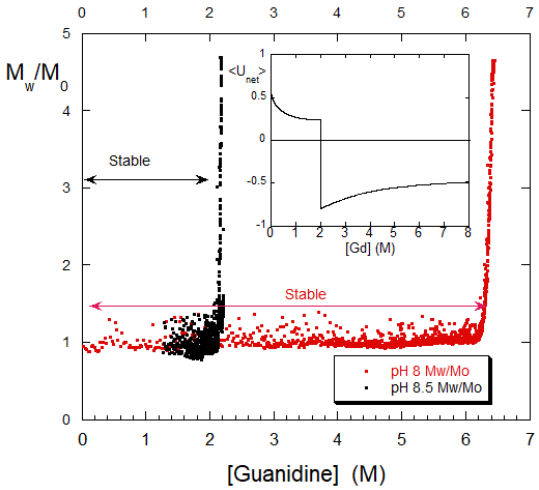


Figure 1: Dialysis of bovine serum albumen against 6M Guanidine-HCl, showing abrupt aggregation at certain values of [Guanidine], dependent on pH. The y-axis shows the relative molecular weight during the process. The inset shows the underlying energetic model for interpreting the results.

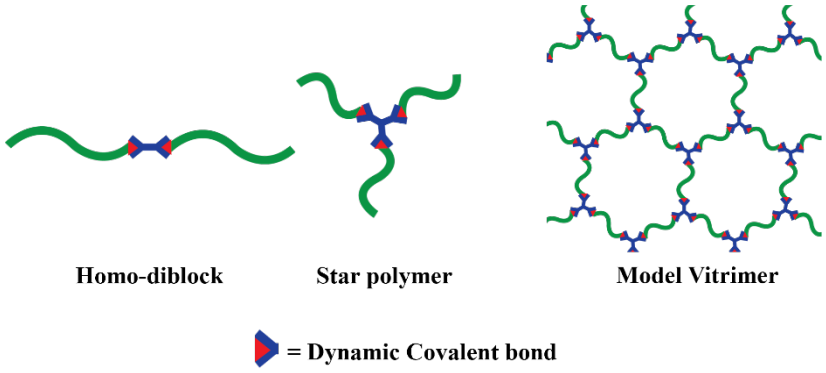
References

1. C.W. Jarand, M.J. McLeod, W.F. Reed, Biomacromolecules, 25, 5198 (2024)

Dynamic Covalent Bond-Based Architectures and Their Characterization

Nikos Hadjichristidis
King Abdullah University of Science and Technology
Saudi Arabia

Polymers featuring dynamic covalent bonds (DCBs) have attracted significant scientific interest due to their ability to form reversible bonds and the wide range of properties (shape memory, self-healing, responsiveness, high toughness, and re-processability) they offer. By replacing permanent chemical bonds with dynamic ones, it is possible to develop innovative materials that combine the toughness of thermosets with the processability of thermoplastics, leading to the formation of covalent adaptable networks (CANs).[1] These materials behave like conventional thermosets at low temperatures but exhibit viscoelastic liquid behavior at high temperatures. Despite the growing demand for these advanced materials, there remains a notable gap in the synthesis and study of model polymers incorporating DCBs. Furthermore, a comprehensive understanding of how DCBs impact macroscopic properties at the molecular level is still lacking. Our group leads these efforts through the synthesis and characterization of well-defined homo-diblocks, star polymers, and three-dimensional networks (vitrimers) incorporating DCBs.[2,3] We have successfully developed dynamic model polymers by employing anionic polymerization - a highly reliable method for synthesizing well-defined model polymers - alongside post-functionalization reactions and DCB chemistry. Our sustained efforts in synthesizing, characterizing, and investigating these materials have unveiled new insights into these systems' chemical stability and dynamic behavior.



Scheme 1: Well-defined homo-diblock copolymer, star polymers, and networks based on DCBs.

References

1. Fan, X.; Zheng, J.; Yeo, J, C, C.; Wang, S.; Li, K.; Muiruri, J, K.; Hadjichristidis, N.; Li, Z. *Angew. Chem.* **2024**, 136, e202408969.
2. Bhaumik, S.; Ntetsikas, K.; Patelis, N.; Peponaki, K.; Vlassopoulos, D.; Hadjichristidis, N. *Macromolecules* **2024**, 57, 1751-1760.
3. Robles-Hernández, B.; Patelis, N.; Arbe, A.; Ntetsikas, K.; Bhaumik, S.; Hadjichristidis, N.; Alegría, Á.; Colmenero, J. *Soft Matter* **2024** (Submitted).

Polymers in Emerging Healthcare and Energy Transition Applications

Sheng Dai
University of Leeds
United Kingdom

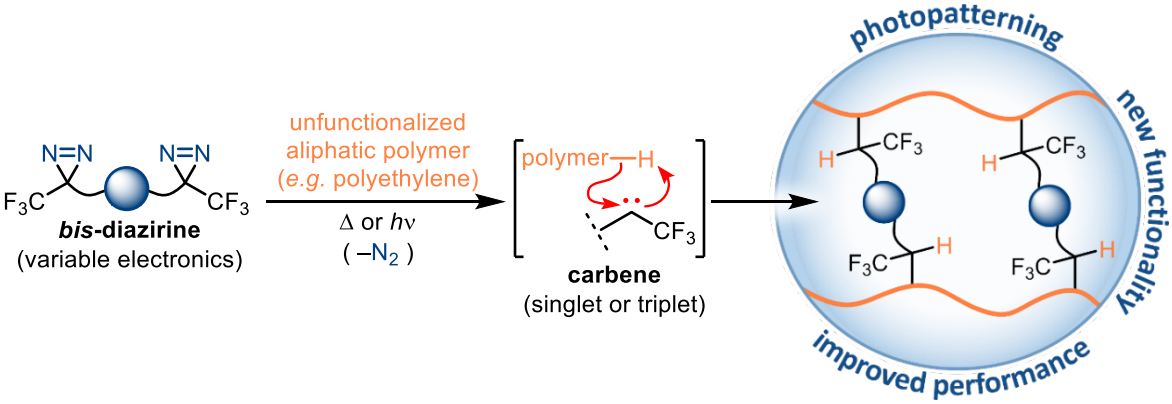
Associated with the specific structure advantages, polymers have been found a broad range of applications in various aspects. Currently, sustainability and health are two critical topics in the world, and polymers have been reported to be versatile to address these global challenges. As biomaterials, polymers and hydrogels are popularly used in tissue engineering, nanomedicine and healthcare devices. On the other hand, polymer, as attractive energy materials, have been fabricated into different types of membranes for fuel cells and hydrogen production. In this talk, recent advance of polymers in healthcare and energy applications will be introduced, structure-property relationship of these polymers and the perspective of polymers in relevant themes will be discussed.

Universal Polymer Crosslinkers for On-Demand Production of Strong, Recyclable Thermoset Composites, Patterned Quantum-Dot Displays, and Low-Loss Dielectric Materials

Jeremy E. Wulff
University of Victoria
Canada

Adding chemical crosslinks between the chains of existing polymer materials provides patternability in microelectronic devices, together with increased mechanical strength, improved high-temperature performance, and enhanced solvent resistance. Installing these crosslinks, however, has historically required the use of distinct chemistry for each type of material: vulcanization for rubber, hydrosilylation for silicone, nucleophilic curing for epoxy resins, electrophilic treatment for cotton fabrics, etc.

We developed a family of rationally designed, diazirine-based crosslinker reagents that allow for the on-demand introduction of strong covalent bonds to virtually any aliphatic polymer material, through rapid C–H, O–H, and N–H insertion reactions. This presentation will focus on industrially relevant applications of these crosslinker reagents, including: (1) adhesion and dyeing of low surface energy materials, (2) upgrading the mechanical strength of ballistic protective fabric, (3) construction of novel fiber-reinforced UHMWPE–epoxy composites, (4) photopatterning of electroluminescent quantum dot aggregates for next-generation displays, and (5) thermal and photochemical curing of 'uncurable' low-loss dielectrics for printed circuit board and semiconductor packaging applications.



References

1. Lepage et al., Accounts of Chemical Research, 2024, 57, 3327.
2. Kandanarachchi et al., Macromolecular Rapid Communications, 2024, 45, 2400200.
3. Fu et al., Journal of the American Chemical Society, 2024, 146, 28895.
4. Bi et al., Angewandte Chemie International Edition, 2023, 62, e202304708.
5. Musolino et al., Polymer Chemistry, 2022, 13, 3833.
6. Musolino et al., Chemical Science, 2021, 12, 12138.
7. Lepage et al., Science, 2019, 366, 875.

Harnessing Dynamically Separated Polymer Nanostructures for Advanced Energy Applications

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Italy

Recent advancements in photonics and catalysis, such as the photon upconversion process, have enabled transformative progress in energy applications including water splitting [1] and photovoltaics [2]. Polymers serve not only as precision-engineered structural components but as dynamic participants in processes modulated by molecular mobility. [3]

Advanced NMR techniques emerge as a critical tool for investigating the structural dynamics and porosity of these systems, providing unparalleled insights into the interplay of material properties and functional performance. Through nanotechnology, hybrid systems are engineered, using hierarchical porous matrices or colloidal dispersions of nanodroplets to optimize energy conversion processes as exemplified in Figure 1. Additionally, polymers play a pivotal role in established energy technologies, such as batteries, where grafted particles [4] enhance the stability and efficiency of electrolytic and electrode systems.

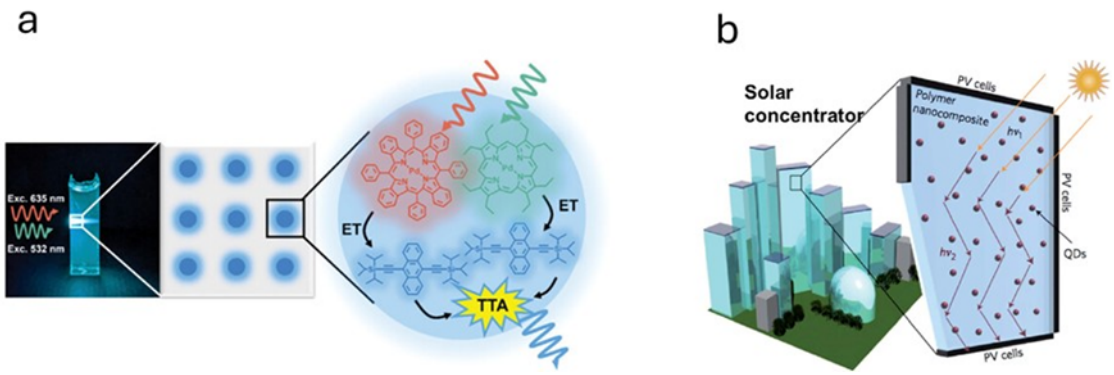

Figure 1: (a) Example of nanostructured material where upconversion is possible within liquid nanodroplets immersed in a structural transparent matrix. (b) Quantum dot nanocomposite for transparent solar panels.

References

1. Erroi, A.; Mecca, S.; Zaffalon, ML.; et al. "Upconversion-Driven Water Splitting Using Molecular Photonic Systems." Nature Energy 2023, 8, 3883-3894
2. Meinardi, F.; Ehrenberg, S.; Dhamo, L.; Carulli, F.; Mauri, M.; Bruni, F.; Simonutti, R.; Kortshagen, U.; Brovelli, S. "Highly Efficient Luminescent Solar Concentrators Based on Earth-Abundant Indirect-Bandgap Silicon Quantum Dots." Nature Photonics 2017, 11, 177–185
3. Hu, X.; Rigamonti, D.; Villa, I.; et al. "Nanostructured Polymers for Enhanced Photonic Energy Conversion." Advanced Materials 2024, 36, 2400443
4. Vallana, N.; Carena, E.; Mezzomo, L.; et al. "Grafted Polymer Particles for Electrolyte Stabilization in Energy Devices." ACS Applied Energy Materials 2024, 7, 1606-1617

Mechanochemistry and Aging-based Methods as Novel Tools to Transform Biopolymers into High Value Materials

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Chitin, the second most abundant biopolymer after cellulose, is present in the shell of crustaceans, in the cuticle of insect and even in some fungi.[1] It can be converted into chitosan, a highly praised material with application as a fertilizer, water treatment flocculant, biomedical fibers and food additive. Further functionalization of these materials is a fantastic avenue for diversification of the use of such materials. Yet the derivatization of these materials has been challenged by complicated liquid state methodologies. Mechanochemistry is becoming an established method for the sustainable, solid-phase synthesis of scores of nanomaterials and molecules, ranging from active pharmaceutical ingredients to materials for cleantech.[2] Beyond its ability to trigger reactivity through energy delivery to chemical systems, mechanochemistry is also a way to activate precursors and mix reagents that may react further in a subsequent aging phase.[3] Biomass being recalcitrant to solubilization are ideal candidate for testing their reactivity by such methods. We showed that mechanochemistry and aging could be used effectively for the deacetylation of chitin using solid NaOH as reagent.[4] This process yielded high molecular weight chitosan with minimal use of energy and solvent. We have also explored the possibility to reduce the molecular weight of chitosan via mechanochemical and aging-based acid treatment,[6] and reported a highly successful alkylation of chitosan with aldehydes.[7] Moving upstream, we have explored the extraction of chitin from crustacean shells, and demonstrated effective extraction of high quality chitin using milling with various solid acids.[5] Chitin, like cellulose, is a crystalline material, granting access to nanocrystals via acid or oxidative partial hydrolysis.[1] Classic methods being water and chemical intensive, we have developed a mechanochemical version, in which aging done under high humidity in a shaker was needed to afford high yields of excellent quality chitin nanocrystals.[8] This method can be extended to cellulose nanocrystals synthesis. Finally, we have also extended the use of mechanochemistry to the fabrication of chitosan nanocrystals from chitin nanocrystals.[9] We developed hydrogels from chitosan and chitin nanocrystals, with exceptional gelling properties and demonstrated their applicability for slow drug release.

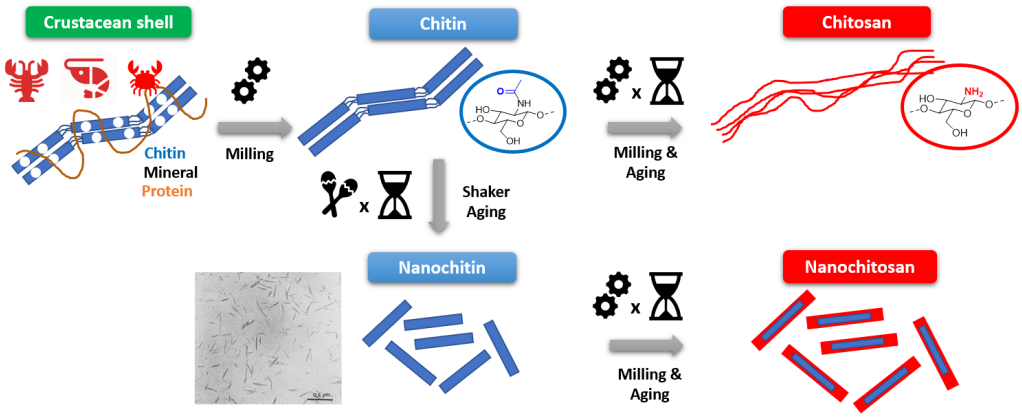

Figure 1. Chitin and chitosan derivates accessed from crustacean shells by mechanochemistry.

References

5. T. Jin, T. Liu, E. Lam, A. Moores, *Nanoscale Horiz.* 2021, *6*, 505-542
6. J.-L. Do, T. Friščić, *ACS Cent. Sci.* 2017, 3, 1, 13−19
7. M. J. Cliffe, C. Mottillo, R.S. Stein, D.-K. Bučar, T. Friščić, *Chem. Sci.*, 2012, 3, 2495-2500
8. T. Di Nardo, C. Hadad, A. Nguyen Van Nhien, A. Moores, *Green Chem.* 2019, 21, 3276-3285
9. F. Hajiali, J. L. Vidal, T. Jin, L. de la Garza, M. Santos, G. Yang, A. Moores, *ACS Sustainable Chem. Eng.* 2022, *10, 34*, 11348−11357.
10. G. Yang, E. Lam, A. Moores, *ACS Sustainable Chem. Eng.* 2023 *11 (20)*, 7765-7774
11. G. Yang, S. Régnier, N. Huin, T. Liu, E. Lam, A. Moores, Green Chem. 2024*, 26, 5386-5396*

12. T. Jin, T. Liu, F. Hajiali, M. Santos, Y. Liu, D. Kurdyla. S. Regnier, S. Hrapovich, E. Lam, A. Moores, *Angew. Chem. Int. Ed.* 2022*, 61 (42)*, e202207206
13. T. Jin, T. Liu, S. Jiang, V. Michaelis, D. Kurdyla, B.A. Klein, E. Lam, J. Li, A. Moores, *Green Chem.* 2021, 23, 6527-6537

Soft Polymeric Nanostructures- Synthesis, Properties and Applications

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Nanotechnology is anticipated to be the next technological wave that will drive many innovations in science and engineering. Self-assembled structures can exist in many different forms, such as spherical micelles, rod-like micelles, bi-layers, vesicles, bi-continuous structure etc. Many living systems, such as plants and marine animals assemble polymeric chains into various nano/microstructures that afford specific functions to these organized structures. Recently, there is a renewed impetus to deconstruct these structures from natural sources and derivatize them for specific applicatons. Thus, new opportunities in the use of sustainable and renewable materials, such as cellulose nanocrystals (CNC) have been advanced and demonstrated. To enhance the utility of these structures, various functionalization strategies on the surface of CNC, such as with amphiphilic polymers, inorganic and metallic nanoparticles are being developed and exploited. The talk will focus on the strategies of CNC functionalization to impart attractive properties critical to their applications. I will illustrate several innovations derived from the transformation of sustainable nanomaterials into platforms that address some of the market requirements and challenges. Some examples of the applications include wastewater treatment, anti-microbial system, conductive inks & fillers, agriculture, and water harvesting.

Plastics for Good: New Materials from Lignocellulosic Biomass

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Lignin, unarguably, represents one of the largest underutilized biological materials resources. One challenge with the valorization of lignin is that most of the extraction processes that are used to isolate this material are accompanied by side reactions that can impact the solubility, chemical functionality and reactivity, and properties of lignin. This presentation will highlight recent work from our laboratory that illustrates the potential of refined extraction processes, which overcome some of these challenges, to provide access to new, lignin-based materials that are of interest for food packaging, antimicrobial, and agricultural applications, amongst others.

The Importance of Polymer Characterization in Consumer Products

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Procter & Gamble
United States of America

Polymers are a backbone material creating delightful consumer experiences in many product categories. These materials are highly complex and have impact on performance, safety, stability, the ability to formulate, and biocompatibility of products consumers use every day. Often the characterization of polymers focuses on the physical parameters of the polymer such as molecular weight, degree of polymerization, glass transition temperature, tensile strength to name a few. To develop polymers of the future we must have the means to characterize their structure and composition more completely. We will share a survey of several different approaches to advance polymer characterization and their importance.

Bio-Based Polymer Innovations for Cosmetic Formulations

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Stanford University
United States of America

Polymers play an important role in cosmetic formulations as stabilizers, thickeners, and film-formers. Synthetic options like polyacrylates are favored for tunability and manufacturing. However, environmental interests have driven a shift toward sustainable polysaccharides for their abundance, bio-based chemistry and enhanced biodegradability. To propel this transition, we describe studies of the physical and chemical properties of polysaccharides to promote opportunities and efficacy in cosmetic formulations (Figure 1).

Unique ex-vivo stratum corneum (SC) fundamental studies were conducted using promising polysaccharides individually and in oil-in-water emulsions containing emulsifiers and benchmarked with synthetic polyacrylate additions. SC drying stress was examined for polysaccharide film forming properties, penetration and sensory perception, synchrotron X-ray diffraction for polysaccharide film forming crystallinity, nanoindentation for film elastic stiffness, differential scanning calorimetry for glass transition, and rheology for dynamic viscosity, all key features for efficacious bio-based formulations. The remarkable effect of polysaccharides on stabilizing micellular formulations and greatly enhancing emollient penetration is reported.

Polysaccharides in formulations can form films with possibilities to engineer film stresses for beneficial sensorial perception and anti-wrinkling properties. Polysaccharide containing formulations have lower dynamic viscosities than those containing polyacrylates at all shear rates, indicating enhanced formulation spreading potential. Polysaccharides films formed from formulations have glass transition temperatures and elastic moduli correlated with their crystallinities, propensity for cracking, and could be rationalized with film gel concentration and resulting film stress. Removing polysaccharides from full formulations destabilized the macroemulsions, significantly lowering their efficacy.

Figure 1: Polysaccharides enhance moisturizing efficacy and provide opportunities for improved sensorial perception and anti-wrinkling.

This work explores how plant-based polysaccharides affect fundamental film formation principles and how stabilized formulations significantly enhance moisturizing efficacy through enhanced emollient SC penetration. Understanding the impact of polysaccharides on skin biomechanics and formulation chemistry is key to designing sustainable biobased cosmetic treatments.

Biomaterials and Tissue Engineering: Characterisation Challenges and Potential Solutions

Neil Cameron
Monash University
Australia

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 some of our work on the development of highly porous polymer scaffolds for 3D cell culture, tissue engineering and regenerative medicine. The materials are produced by a technique known as emulsion templating, which generates porous polymers (polyHIPEs) with a very well-defined and fully interconnected network of pores in the size range 10-100 microns. Features such as the pore diameter, degree of interconnection, porosity, mechanical properties and surface chemistry can be tailored to produce materials designed for different applications. The presentation will feature some recent case studies from our laboratory [1-3], on the regeneration of soft and hard tissues such as neural tissue and bone. In particular, characterisation challenges presented by the lack of optical transparency of the scaffolds will be discussed, together with practical solutions.

Scaffolds for Cultured Fat with Low Cholesterol and Better Lipo-nutritional Properties

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People' s Republic of China

Cultured fat is an essential component of cell-cultured meat. However, few studies have been on regulating the nutritional composition of cell-cultured meat, especially concerning the deposition of cholesterol and lipo-nutritional quality. We generated a KA scaffold using konjac glucomannan and alginate hybrid hydrogel, which can effectively support the formation of tissue-like cultured fats from both subcutaneous preadipocytes (preSAT) and fibro-adipogenic progenitors (FAPs). Interestingly, we find that phosphatidylcholine (PC) treatment significantly increases lipid accumulation and alters the lipid composition of cultured fat. We further generated KP scaffold by introducing functional PC nanoparticles (PC NPs) into KA hydrogel. Interestingly, such an innovative strategy enhanced the lipo-nutritional of cultured fat with a significant reduction in cholesterol levels. Our findings provide creative approaches for producing cultured fat with low cholesterol and better lipo-nutritional quality.

"Devilish", Responsive Polymer Surfaces: The Characterization Challenge

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University of Twente
Netherlands

For a long time, the properties and behavior of surfaces were characterized by macroscopic mechanical measurements, like adhesion, friction, and fracture. Although Thomas Young described contact angle measurements and their relationship to surface tension at the beginning of the 18th century, precise methods to determine contact angle values and surface tension were only developed in the 20th century. Breakthroughs in the understanding of the rules that govern the physical and chemical behavior of surfaces have been enabled and accelerated by the developments of modern surface layer characterization techniques, including reflection of infrared radiation, neutrons and X-rays, surface force and molecular level imaging measurements such as atomic force microscopy (AFM), surface charge determination, surface chemical composition by X-ray photoelectron and Auger electron spectroscopy, and secondary ion mass spectrometry. In this presentation, we give an account of some selected applications to study dynamic surfaces and stimulus-responsive polymer brushes by using many of these methods as it took place in our laboratories.

We begin the examples with studies of hydrophobic recovery by using chemically modified AFM tips, focusing on UV/ozone-treated, cross-linked PDMS. The results demonstrate a gradual formation of a silica-like layer at the top with increasing radiation dose, and provide a basis for surface hydrophilization, with relevance to microfluidics and biomedical applications of silicon rubber.

In the second example, we first show AFM imaging and probe the responsive behavior of the chain collapse dynamics of poly(N-isopropyl acrylamide) brushes by AFM. Then, we turn our attention to probing a notoriously difficult characteristic of polymer brushes, i.e., determining the grafting density by colloid-probe AFM compression measurements. To this end, we use the de Gennes "box" like polymer model to evaluate the AFM compression force and obtain grafting density values.

The third example involves switching the transport through nanopores with pH-responsive polymer brushes for controlled ion permeability. The results demonstrate the potential of this approach to nanoscale valve applications.

Positioning light emitters in photonic crystals promises to bring such systems to the next level of function control, e.g., in optical computing and "smart" photonics. In the last example, we show how to precisely position semiconductor quantum dots utilizing brush polymer chemistry inside 3D silicon photonic band gap crystals and characterize the system's optical/spectral behavior.

These examples demonstrate how surface characterization paves the way to understand and describe polymer brush structure-property relations and open their technology transformations in controlled vetting, molecular gating in fluidics and filtration, and nanoscale positioning of light emitters in brush-coated microstructures as selected examples.

Slide-Ring Materials for Circular Economy

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University of Tokyo
Japan

We have developed a novel type of polymeric materials such as slide-ring (SR) materials and pseudo-polyrotaxane (PPR) nanosheet with cyclodextrins (CyDs) for sustainable engineering. In the SR materials, polymer chains are topologically interlocked by figure-of-eight cross-links.[1)] Hence, these cross-links can pass along the polymer chains freely to equalize the tension of the threading polymer chains similarly to pulleys. Recently, we have just reported the stretch induced crystallization of the SR gel, which leads to extremely high toughness and recoverability.[2)] The concept of the slide-ring gel is not limited to cross-linked gels but also includes elastomer[3)], resins[4)], and composites[5)]. Accordingly, it can be applied to wide area such as paints, rubbers, soft actuator, batteries, and so on.[6,7)] The slide-ring materials were used as a key technology to create tough and sustainable polymers for circular economy.

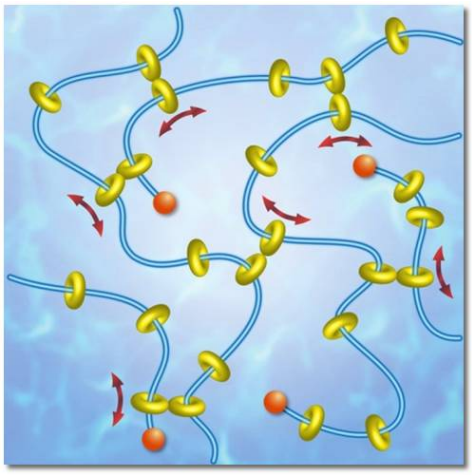

Fig.1. Schematic diagram of Slide-Ring materials.

References

1) Y. Okumura and K. Ito, *Adv. Mater.*, **2001**, 13, 485.
2) C. Liu, N. Morimoto, L. Jiang, S. Kawahara, T. Noritomi, H. Yokoyama, K. Mayumi, K. Ito, *Science*, **2021**, 372(6546), 1078.
3) H. Gotoh, C. Liu, A. B. Imran, M. Hara, T. Seki, K. Mayumi, K. Ito, Y. Takeoka, *Sci. Adv.*, **2018**, 4(10), eaat7629.
4) S. Ando, M. Hirano, L. Wakatabe, H. Yokoyama, K. Ito, *ACS Mater. Lett.*, **2023**, 5, 3156.
5) T. Goto, T. Ito, K. Mayumi, R. Maeda, Y. Shimizu, K. Hatakeyama, K. Ito, Y. Hakuta, K. Terashima, *Comp. Sci. Tech.* **2020,** 190, 108009.
6) Y. Noda, Y. Hayashi, and K. Ito, *J. App. Polym. Sci.*, **2014**, 131**,** 40509. 7) K. Hashimoto, T. Shiwaku, H. Aoki, H. Yokoyama, K. Mayumi, K. Ito, **Sci. Adv.**, **2023**, 9(47), eadi8505.

Scalability Aspects of Polymeric Materials from the Viewpoint of Fire Protection

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Various testing methodologies are generally adopted to understand the different parameters associated with the thermal and flammability properties of polymeric materials. Almost 95% of the published academic literature in this field revolves around employing some of these testing approaches, which are primarily at smaller length scales. Even at these scales, correlations between parameters obtained from different tests like cone calorimeter (like heat release rates, total heat release, time to ignition, fire growth rate, etc.) with their corresponding Underwriter Laboratories (UL) 94 ratings and/or limiting oxygen index (LOI) measurements are hard to find. More importantly, when designing polymeric systems for the construction industry involving structural applications, regulatory requirements demand the testing of the protected members to meet certain fire resistance criteria (e.g. deflection limits and/or critical temperature) with the imposed mechanical and thermal loads according to standard fire tests. These fire resistance tests and other reaction to fire tests (such as EN13501-1 / EN13823, BS476 Part 21, ASTM E119 or EN 13381-8) are usually time-consuming, expensive, and require a lot of resources. In this context, many questions arise on the usefulness and validity of thermal and flammability tests at smaller length scales. In this talk, a thorough discussion on this will be presented with consequences regarding scalability to the market and for required applications.

Novel Separations for Complex Architectures – from Single Chain Nanoparticles to Multichain Assemblies

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Recent developments in field flow fractionation (FFF) enable the separation and the extensive characterisation of intricate macromolecular architectures and their hybrids. The advancement in theoretical understanding, technology and design of thermal (ThFFF) and asymmetric flow (AF4) field flow fractionation enable insights into new levels of structural distributions allowing a precise separation and recognition of small macromolecular variations and their structure.

This presentation gives an overview of different questions of compositional distributions, such as the scaling properties of single-chain nanoparticles depending on their structural parameters based on AF4 multidetection,[1] chain-walking polyolefins with a specific bottle-brush branching architecture as well as the indication of ring formation in polyester structures based on their thermophoretic properties by ThFFF.[2]

New developments in detection and technology in FFF make the separation and analysis of "difficult" polymers possible. In contrast to highly branched chain-walking polyolefins, analysis of high-performance industrial polyolefins is challenging, especially when ultra-high molecular weights or extremely long-chain branching combined with low solubility at ambient temperatures are involved. HT-ThFFF can overcome this limitation as its separation mechanism is gentle and intrinsically sensitive to branch separation. A novel design for ThFFF separation in an high temperature environment enables the effective separation of highly complex polyolefins.[3]

ThFFF can also help separate delicate hybrid structures due to the gentle forces applied during separation. A good example is the distribution of the composition of polymer-metallic nanostructures, which could be visualised for the first time using three-dimensional correlation ThFFF (3DCoThFFF). This method enables the analysis of multiple sizes, shapes, compositions and their respective distributions that are synchronously correlated by time-resolved LSPR as derived from multiple 2D UV-Vis spectra per ThFFF time unit.[4]

Compared to ThFFF, AF4 is well known for the characterisation of carrier systems for drugs or enzymes based on synthetic polymer vesicles, though limited in terms of detection to sizes larger than 20 nm. [5] Distribution of multiple parameters such as small polymer micelles, and thickness of polymersome membranes in combination with their stability, loading, and release properties are difficult to interpret even with multiple light scattering or viscosity detectors. A coupling of AF4 with powerful scattering techniques, such as SAXS opens new avenues to characterize such small structural dimensions and their distributions and understand their role in new biohybrid systems.

References

1. J. Engelke et al. ACS Macro Lett 2020, 9, 11, 1569−1575
2. M. Geisler et al. Macromolecules 2019, 52 (22), 8662−8671; W. C. Smith et al. Anal. Chem. 2019, 91, 19, 12344−12351
3. M. Geisler, A. Lederer (2004) Bauteil und Verfahren zur thermischen Feldflussfraktionierung bei Hochtemperatur, 202405301431500DE, DPMA
4. U.L. Muza et al. Anal. Chem. 2023, 95, 29, 11085−11090.
5. H. Gumz et. al, Adv. Sci. 2019, 1801299; M. Palinske et al, Macromol. Chem. Phys. 2023, 224, 2200300.

In-line Model Supported and Data-Driven Optimization of Technical and Functional Polymer Processing

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Denmark

Large-scale industrial processing methods like roll-to-roll (R2R) coating and polymer spinning necessitate characterization methods that match the speed and volume of these techniques. I will present methodologies to optimize and control the processing of high-performance polymeric materials, with the aim of improving quality control and enabling real-time data analysis for industrial applications. The approach leverages specialized X-ray and visible light imaging and scattering equipment, along with machine-learning-assisted analysis, to match the speed of industrial processing and ensure high-quality production.

In situ X-ray scattering has emerged as a high-throughput method for analyzing the effects of processing parameters and the kinetics of structure formation in real-time. This method allows for detailed analysis of semi-crystalline nanostructures in thin films coated on flexible substrates. High-resolution analysis of a wide parameter space is achieved by recording thousands of experimental variations along the substrate foil, enabling detailed structural analysis using fast testing devices and high-flux X-ray beams. This approach allows for precise control of component concentrations and other parameters, facilitating high-throughput analysis.

The development of an in-line methodology supported by molecular dynamics simulations aims to optimize mesoscale structure formation for improved photovoltaic performance. Furthermore, visible light scatterometry is proposed as a quality control tool for R2R fabrication lines, capable of analyzing surface structures and functional coatings with high resolution. The combination of scatterometry data with machine learning enhances the robustness of the analysis, supporting solutions for decentralized decision-making based on real-time structural properties.

Fast small and wide-angle X-ray scattering can be applied to monitor and optimize solution spinning of high-performance polymers using machine-learning assisted analysis of scattering parameters that are correlated with mechanical properties.

The proposed methodologies are developed to be applicable not only at synchrotron beam lines, but also with laboratory-scale setups. By integrating multimodal probes and machine learning techniques, this approach aims to bridge the gap between laboratory research and commercial production of polymeric materials and devices.

AI/ML in Additive Manufacturing and Polymer Synthesis for New Data and Discovery

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Creating and curating new data appends the way we approach materials science. In additive manufacturing (AM), the fabrication of parts and objects with high complexity and high performance is advantageous over other methods. Using nanocomposites enables highly improved properties even with "commodity polymers" that do not need to undergo high-temperature processes or extensive reformulation. With artificial intelligence and machine learning (AI/ML), optimizing the formulation and manufacturing methods is possible. Using sensors capable of a feedback loop mechanism and the ability to use simulation to create digital twins, optimizing properties in record time is possible. Statistical and logic-derived design, including regression analysis, are starting points for designing experiments (DOE) or principal component analysis(PCA) in optimization and analysis vs trial-and-error approaches when working with polymer materials. In this talk, we demonstrate the approaches toward understanding Nanostructuring in composites and hierarchical approaches in optimization via AI/ML and other training/learning sets for specific properties and applications, such as 3D printing and flow chemistry reactions. Introducing more sensors (monitoring instruments) in AM processes and real-time ML with online monitoring allows a feedback loop and deep learning (DL) for autonomous fabrication and data analytics.