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PREFACE

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Emerging Directions in Polymer Interfaces, Adhesives, and Functional Coatings

Polymer science continues to play a transformative role in materials innovation, enabling breakthroughs across diverse domains including energy storage, flexible electronics, surface engineering, and soft robotics. At the heart of these advances lies a critical, often defining factor: the interface. Whether between polymers and solid substrates, liquids, gases, or other polymers, interfacial phenomena govern adhesion, wetting, energy dissipation, chemical reactivity, and signal transmission. Interfaces are not passive boundaries but active zones of complexity and function, where molecular interactions shape material performance at every scale—from nanometers to entire devices.

Understanding and engineering polymer interfaces is essential for solving pressing challenges in durability, responsiveness, environmental sustainability, and multifunctional integration. Advances in this area demand cross-disciplinary insights spanning chemistry, physics, and mechanics, as well as new tools for characterization, modeling, and design.

This special topic brings together 1 review article and 10 research articles, offering a comprehensive view of current progress in polymer interfacial science, smart surfaces, functional adhesives, and soft-matter processing, with an emphasis on both mechanistic understanding and application-driven innovation.

The topic opens with a broad review on anti-icing and de-icing surface materials, summarizing recent developments in passive and active polymer coatings designed to resist snow and freezing disasters—an exemplary case where interfacial control directly impacts performance in extreme environments. The remaining 10 articles are grouped into four thematic categories that reflect the growing scope and depth of polymer interface research.

(1) Surface Engineering and Smart Interfaces

This section features studies on thermoresponsive elastomeric films, photoresponsive superwetting surfaces, humidity-resistant wrinkle patterns, and rewritable functional coatings. These studies demonstrate how precise control over interfacial chemistry, topology, and mechanics enables real-time modulation of surface properties, unlocking capabilities in sensing, information display, filtration, and soft actuation.

(2) Interfacial Adhesion and Composite Performance

Drawing inspiration from biological adhesion systems such as nucleobase pairing and amyloid-like structures, these articles highlight the role of multivalent interactions, interfacial matching, and molecular synergy in achieving strong, recyclable, and environment-tolerant bonding. The use of Janus particles for fiber sizing further exemplifies how rational interfacial design enhances stress transfer, toughness, and long-term integrity in composite systems.

(3) Energy and Functional Materials

One study introduces a fluorine-free polysulfone-polyamide-polyimide binder that improves adhesion and interfacial compatibility in lithium-ion battery cathodes. This work underscores how electrode-electrolyte interfaces influence ion transport, electrochemical stability, and lifecycle performance—areas where polymer interfaces directly determine the viability of energy technologies.

(4) Polymer Dynamics at Interfaces

Fundamental insights into interfacial adsorption, molecular mobility, and flow behavior are explored through studies on polystyrene-graphene systems and drying dynamics in PEO solutions tracked *via* 3D holography. These contributions reinforce that nonequilibrium interfacial processes are central to pattern formation, structure evolution, and functional coating design.

Together, the contributions in this issue reaffirm the interface as a nexus of innovation in polymer science. They highlight how strategic control of interfacial phenomena enables materials that are not only structurally robust and chemically stable, but also adaptively functional, environmentally responsive, and dynamically tunable. We hope this collection stimulates further exploration across academia and industry, and supports the continued advancement of polymer science toward addressing both scientific challenges and societal needs.

Jian-Jun Wang
Guest Editor

Guang-Zhao Zhang
Guest Editor

Shou-Ke Yan
Associate Editor

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