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PREFACE

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Special Topic on Functional Gels

Functional gels are an important class of soft polymer materials that combine solvent-rich network structures with tunable mechanical, transport, interfacial, and responsive properties. Owing to their structural similarity to biological tissues and their broad design space in polymer chemistry, supramolecular interactions, phase behavior, and network dynamics, functional gels have attracted growing interest in biomedical materials, flexible electronics, soft robotics, energy devices, environmental technologies, sensing systems, and advanced manufacturing.

In recent years, the development of functional gels has moved beyond the improvement of individual properties toward the integrated regulation of structure, dynamics, and function. Molecular design, dynamic crosslinking, phase separation, interfacial engineering, and multiscale characterization have provided new opportunities to understand and control gel behavior across different length and time scales. It is therefore timely to organize this special topic on "Functional Gels" in the *Chinese Journal of Polymer Science*, aiming to present recent progress and emerging directions in this rapidly developing field.

We are pleased that our call for contributions received enthusiastic responses from the community. This special topic collects 17 contributions, including 1 feature article, 7 review articles, and 9 research articles. These papers cover a broad range of topics in functional gels, including gel physics and characterization, functional ionogels, hydrogel bioelectronics, soft iontronics, anti-biofouling hydrogels, energy-dissipating gels, catalytic hydrogel platforms, mechanically adaptive hydrogels, micro-rheology, wearable sensing, ophthalmic drug delivery, and soft robotic motion. Together, they provide a timely snapshot of current research activities in functional gels and reflect the breadth and vitality of this field.

This special topic highlights both fundamental understanding and application-oriented innovations, emphasizing the following themes.

(1) Gel physics, characterization and dynamics. Yu-Sen Jie and Di Jia[1] discussed advanced light scattering characterization and physics for functional polyelectrolyte gels. By summarizing the theory and methodology of dynamic and static light scattering, this feature article highlights how microscopic physical interactions, crosslinking density, and hierarchical gel dynamics can be quantitatively connected to macroscopic gel behavior. Bing-Hui Xue, Yuan Liu and Pan-Chao Yin[2] developed a depolarized dynamic light scattering micro-rheology method using anisotropic tracer nanoparticles, which improves the contrast and accuracy of gel viscoelasticity measurements. Yu-Xuan Pei, Quan Chen and Hiroshi Watanabe[3] investigated nonlinear stress relaxation in associative polymer systems, revealing how transient network structures evolve under large deformation. These contributions emphasize that reliable characterization of dynamics, relaxation, and physical interactions is essential for establishing structure–property–function relationships in functional gels.

(2) Network design, phase behavior and mechanical functions. Xue Wang, Xin Fu, Lie Chen and Ming-Jie Liu[4] summarized phase-separation-enabled functional ionogels, showing how ionic liquids, polymer networks, and multiscale phase behavior can be combined to regulate mechanical, interfacial, and electrical properties. Rui Wu, Jin-Qi Zhang, Xun Xiao and Mei-Xiang Wang[5] provided a comprehensive review of functional ionogels, with emphasis on design-enabled self-healing, shape-memory, stimuli-responsive, adhesive, and other functional properties. Wei Shi, Zong-Zheng Zhang, Jin Huang, Ming-Jie Liu and their colleagues[6] reviewed high-energy-dissipation polymer gels by regulating the relaxation of confined chains within elastic networks. Yi Yu, Wei Zhou, Tao Chen and Wei Lu[7] reported water-swelling-induced stiffness enhancement of polymer hydrogels through water-induced phase separation. Chen-Chen Lou, Bao-Hu Wu, Sheng-Tong Sun and Pei-Yi Wu[8] developed a transparent acoustic damping hydrogel based on dual-scale bicontinuous microphase separation. Shu-Xing Yin, Chuang-Qi Zhao, Lei Jiang and their colleagues[9] reported strong and tough high-water-content double-network hydrogels based on bacterial cellulose and poly(vinyl alcohol). These works demonstrate how phase separation, hydrogen bonding, polymer crystallization, dynamic association, and double-network construction can be used to reconcile softness, stiffness, toughness, damping, and environmental responsiveness.

(3) Biointerfaces, wearable sensing and soft iontronics. Yu Xue, Fu-Cheng Wang, Ji Liu and their colleagues[10] reviewed direct-ink-writing 3D printing of hydrogel bioelectronics, focusing on hydrogel ink design, printability, conductivity, tissue adhesion, and biointerface applications. Sen Liu, Heng Zhan, Lu-Wei Zhang, Zi-Zhi Wang and Zhou-Yue Lei[11] discussed soft polymer iontronics for neuromorphic intelligence, highlighting ionic signal transduction, artificial synapses, viscoionic relaxation, and adaptive sensing. Li-Ping Lang, Wen-Guang Liu, Jian-Hai Yang and their colleagues[12] contributed the cover article,

which focuses on anti-biofouling hydrogels and highlights surface hydration, hydrogen-bonding hydration, ion-solvation hydration, and biomedical applications. Xiao-Jiao Shi, Ti-Feng Jiao, Zhi-Hui Qin and their colleagues[13] reported interface-engineered ionically conductive polyoxometalate-based hydrogels with high stretchability and notch-insensitivity for wearable sensors. Yu-Hao Zhang, Kun Yang, Hu-Lin Zhang and their colleagues developed a self-powered posture recognition system based on thermoelectric hydrogels. Xin Yang, Hai-Hua Wang, Shi-Lei Zhu, Ya-Nan Ye and their colleagues[14] reported an *in situ* formed polysaccharide hydrogel for sustained ophthalmic drug delivery. These contributions show how gel materials can bridge soft biological tissues and functional devices by integrating mechanical compliance, transport capability, interfacial stability, and biological safety.

(4) Interfacial platforms, soft actuation and emerging applications. Jia-Xin Gao and Wen-Wei Lei[15] reviewed hydrogel-based self-floating catalytic materials for interfacial solar-driven chemistry, pollutant degradation, and sustainable energy conversion. By constructing stable three-phase interfaces, these materials enhance light utilization, mass transfer, and catalytic efficiency. Han-Lei Cheng, Qing-Li Zhu, Zhi-Jian Wang, Josef Breu and Zi-Liang Wu[16] reported pre-twist-dependent configurations of hydrogel rings and their distinct modes of self-sustained locomotion, demonstrating how internal stress, topology, and anisotropic responsiveness can generate autonomous soft motion under light irradiation. Together with studies on acoustic damping, stiffness switching, and self-powered sensing,[7,8,17] these works illustrate the potential of functional gels to operate as adaptive materials that convert environmental stimuli into mechanical motion, signal output, or chemical function.

During the editorial process of this special topic, it became evident that functional gels represent a highly dynamic and interdisciplinary area of polymer science. The contributions collected here show that the significance of functional gels lies not only in the diversity of achievable properties, but also in their ability to integrate mechanics, transport, responsiveness, interfacial compatibility, and biological or device functions within a single soft material system. We hope that this special topic will provide useful references for researchers in polymer science and related fields, stimulate further fundamental studies on gel networks and soft matter dynamics, and inspire new applications of functional gels in biomedical engineering, flexible electronics, intelligent devices, environmental technologies, and soft robotics.

Finally, we would like to express our sincere gratitude to all contributing authors for their excellent work and thoughtful contributions, to the reviewers for their rigorous and constructive evaluations, and to the editorial office of the *Chinese Journal of Polymer Science* for their professional support and efficient coordination. As guest editors, we hope that this collection will promote further interdisciplinary collaboration and contribute to the continued development of functional gels from fundamental polymer science to advanced materials and practical technologies.

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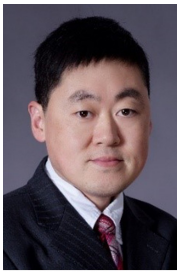

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