

Gels: from biomaterials to flexible electronics

Yong Mei Chen

College of Bioresources Chemical and Materials Engineering, National Demonstration Center for Experimental Light Chemistry Engineering Education, Shaanxi University of Science & Technology, Xi'an, 710021, PR China

*E-mail: chenyongmei@sust.edu.cn

Gels have drawn immense research attention in biomedical engineering and flexible electronics, which demand multifunctionality, intelligent responsiveness and mechanical robustness. A key material design trade-off persists: biomaterial-targeted gels require a balanced combination of biological functionality, dynamic performances (injectability, self-healing, self-recoverability, reversibility, remouldability) and mechanical strength; conductive gels for flexible electronics need to retain stable ionic conductivity alongside improved tensile capability, tear-resistance and anti-fatigue performance.

To alleviate the conflict between dynamic network rearrangement and mechanical toughness, biopolymer hydrogel platforms are built via multiple types of dynamic bonds. Incorporated nanoparticles serve three distinct roles: nanocrosslinkers for network reinforcement, red-fluorescence sources, and carriers for stepwise protein release. These biocompatible dynamic hydrogels act as sequential pH responsive protein delivery platforms and ambient-temperature storage matrices for stem-cell constructs, bypassing complex cryopreservation and cold-chain logistics.

Tough organogels and ion-conductive gels are fabricated through nacre-inspired microphase-separated design, fiber reinforcement and multiscale interfacial engineering. They deliver high tensile strength, fracture energy and fatigue threshold, rapid self-recovery and broad environmental tolerance, and withstand repeated dynamic loading with anti-fatigue, anti-puncture and impact-resistant features. For flexible-electronic scenarios, organogel-based ionotronics enable intelligent continuous-passive-motion systems for personalized postoperative rehabilitation and telemedicine; anti-puncture organogel sensors are integrated into smart trocar-seal assemblies for real-time laparoscopic monitoring; ionogel-leather ionic skins realize multi-modal physiological sensing and human-machine interaction, as validated by smart-glove prototypes. Collectively, these strategies build a versatile gel platform synergizing reversible-crosslinking chemistry, ionic transport and mechanical-energy dissipation, providing a feasible path toward next-generation soft materials for biomedical applications and wearable electronics.