



Interfacial Design of Charged Polymer Nanoparticles and Their Functional Applications

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ABSTRACT

The structural and morphological design of charged polymer nanoparticles is crucial for regulating interfacial functions and enables broad applications in adhesion, water transport, and functional sensing. In this work, a library of charged nanoparticles was constructed, including core-shell particles, Janus particles, and tadpole-like single-chain nanoparticles, with systematic control over particle composition, asymmetry, and charge distribution. On inert solid surfaces, tadpole-like single-chain nanoparticles form uniform and stable monomolecular layers through multivalent head-group anchoring and electrostatic repulsion between charged heads, thereby significantly improving interfacial adhesion compatibility and stability. Within hydrogel networks, interpenetration and entanglement of polyelectrolyte shells generate a surface layer with a high density of charged polymers. The long-range electrostatic interactions between polymers and water regulate the hydrogen-bonding structure of water, leading to accelerated water transport and tunable evaporation rates. This interfacial strategy can be further extended to enhanced Raman sensing platforms, where an “active enrichment-enhancement” mechanism enables rapid, broadband, and highly sensitive detection of environmental contaminants. These results provide a versatile design framework for the development of multifunctional interfacial materials based on charged polymer nanoparticles.

BIOGRAPHY

Dr. Xiayun Huang is an Associate Professor in the Department of Macromolecular Science at Fudan University and the Principal Investigator in the State Key Laboratory of Molecular Engineering of Polymers. She also serves as Deputy Director of the Center for Advancing Global Collaboration at Fudan University. Her research focuses on the self-assembly of charged assemblies and their functional applications at surfaces and interfaces. She has received past fundings from Natural Science Foundation of China (NSFC) and participated in the Key R&D Young Talent Program, Dow Innovation Challenge Research, etc. She is an awardee of Shanghai Pujiang Talent Award and Emerging Investigator of Journal of Material Chemistry A. She has 40+ peer-reviewed publications in Adv. Funct. Matter., etc. and has been invited to deliver more than 50 academic presentations at international venues including Shiseido Beauty Beyond, the IUPAC Macro Conference, and the Kavli Institute for Theoretical Science. She also serves as editorial board member of Scientific Reports, and youth editorial board member of Nano-Micro Letters, Chem & Bio Engineering, and Supramolecular Materials.