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Highly Elastic and Underwater Superoleophobic Polypyrrole-Coated Starch Cryogels for Water Purification

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ABSTRACT

The global water crisis continues to worsen, primarily due to widespread freshwater contamination. Effective water treatment methods are essential for addressing this issue, especially given the increasing presence of nonpolar pollutants such as oils and dissolved contaminants like heavy metals, salts, and nitrates. These pollutants significantly complicate the purification process. While existing treatment technologies—such as membrane filtration, ion exchange, distillation, adsorption, chemical precipitation, and coagulation—offer some solutions, developing a cost-effective, energy-efficient, and environmentally sustainable approach remains a challenge.

In this study, we present an eco-friendly water purification method using biodegradable starch cryogels coated with polypyrrole (PPY). Starch, an abundant, renewable, and low-cost natural polymer, was used to fabricate cryogels with an interconnected porous structure. These cryogels were then coated with PPY nanoparticles to enhance their hydrophilicity. The resulting material enabled wastewater purification through two mechanisms: (1) oil/water separation via filtration and (2) solar-driven water evaporation, facilitated by the PPY nanoparticles' efficient sunlight absorption and thermal energy conversion.

The fabricated starch cryogels demonstrated outstanding mechanical robustness, compressive elasticity, and flexibility, with the ability to withstand significant deformation, including compression, bending, and folding. Scanning Electron Microscope imaging confirmed the formation of interconnected porous scaffolds loaded with PPY nanoparticles, which significantly enhanced the cryogels' mechanical properties. Furthermore, the cryogels exhibited excellent underwater superoleophobicity against various organic oils, including corn oil, olive oil, hexane, dichloromethane, chloroform, and carbon disulfide, with underwater oil contact angles exceeding 150°. Oil separation tests further confirmed a filtration efficiency of over 99%, demonstrating the cryogels' effectiveness in removing oils from water. This study highlights the potential of starch-based cryogels as a sustainable and efficient solution for industrial wastewater treatment, offering a promising approach for large-scale water purification applications.