Functional Multiphase Systems Stabilized by Protein–Cellulose Nanocomposites

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Cellulose nanocrystals (CNCs), as charged rod-like nanoparticles, have attracted significant attention as eco-friendly stabilizers for Pickering emulsions. However, their inherent hydrophilicity often requires surface modification to achieve optimal interfacial performance. In this study, we propose a biomimetic strategy to fabricate programmable cellulose nanocomposites through the integration of CNCs with phase-transitioned bovine serum albumin (PTB). Specifically, reduction of disulfide bonds in bovine serum albumin induces amyloid-like aggregation, enabling rapid self-assembly of PTB oligomers onto CNC surfaces. The resulting PTB/CNC nanocomposites synergistically combine the enhanced interfacial activity of the hybrid particles with bioadhesive properties arising from protein structural reorganization. The hybrid nanocomposites exhibit excellent interfacial stabilization capabilities and spontaneously adsorb at fluid interfaces, enabling effective stabilization of both oil-in-water and water-in-water emulsions. Moreover, the interfacial behavior and stabilization performance can be precisely tuned by adjusting the PTB-to-CNC ratio, allowing programmable control of the nanocomposite architecture and emulsion properties. These nanocomposite-stabilized emulsions demonstrate strong potential for sustainable agricultural applications, such as precision pesticide delivery. More broadly, the programmable interfacial assembly strategy provides a versatile platform for developing functional soft materials with controlled droplet deposition and surface adhesion, with potential applications in functional coatings, cosmetic formulations, and targeted drug delivery systems.

Keywords:
CNC, Interfacial Assembly, Multiphase Systems

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