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Sustainable Soft Matter Systems: Bioderived nanomaterials and Biocatalysis

The urgent need for sustainable chemical synthesis and material innovation has accelerated research at the intersection of soft matter science, bio-derived nanostructures, and green chemistry. This presentation demonstrates ongoing research at Macromolecular Nanomaterials Group on sustainable soft matter systems that leverage biological feedstocks and enzymatic processes to advance circular polymer technologies.

We first demonstrate the use of mycelium-derived polyscacchirdes as a renewable and structurally robust filler for polymer composites, enabling enhanced mechanical performance while maintaining biodegradability. With low loading (< 5% wt.), the reinforcement effect of these particles in polyvinyl alcohol (PVA) hydrogel is comparable to that of nanoscale cellulosic particles (CNCs) and graphene oxides (GOs) additives—of which typically require harsh conditions such as strong acids and elevated temperatures during synthesis. Variations in chemical composition and particle morphology (fibrous structures vs. dense particles) among mycelium from different fungal species contribute to significantly different reinforcement outcomes. In some cases, the biosynthesis and chemical extract approaches used for filler preparation also enable polyscacchirdes deuteration for contrast match technique in neutron scattering experiments. In addition to hydrogel, we present strategies for electrospinning bioderived molecules—such as lignin derivatives, cellulose nanocrystals, and biosynthesized polymers—into functional nanoscale fibers with tailored morphology and functionality. Finally, we highlight research on the biocatalytic synthesis of aliphatic polyesters in vitro via lactone ring opening polymerization using hydrolases as catalysts in a biphasic system. This approach offers mild, selective, and solvent-efficient routes to polymer formation. The microstructures of resulting block copolymers can be tuned through enzyme selectivity, yielding materials with distinct physical properties such as crystallinity.

Together, these approaches from synthesis to material processing illustrate a cohesive vision for integrating materials science with biology to design next-generation soft matter systems that are both high-performance and sustainable.

Topical Area

Soft matter: polymers, and complex fluids

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