Designer Circular Composites through Cold Sintering for Structural and Energy Storage Applications

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Composites provide critical performance characteristics to improve energy efficiency in many applications, but they are generally difficult to recycle. Cold sintering, a process that consolidates inorganic powders at temperatures far below conventional sintering, offers a transformative approach to fabricating sustainable ceramic composites that are fully recyclable. The low temperatures of cold sintering enable the integration of diverse components, including plastics, into dense composites. We demonstrated plastic waste upcycling into fully recyclable composites through cold sintering for durable structural materials[1]. The resulting inorganic-matrix composites, containing recycled plastics, exhibit enhanced tensile strength and toughness. After grinding, these composites can be recycled via cold sintering, maintaining their mechanical properties with minimal energy and resource input. This makes them a sustainable alternative in the construction industry, with significantly lower greenhouse gas emissions compared to conventional materials.

The mechanical strength of these cold-sintered composites is closely tied to morphology. Minor maleation (~1%) of polypropylene (PP) increases the interfacial area between organic and inorganic components, forming a hierarchical structure confirmed by μ-CT and electron microscopy[2]. By modifying polymer chemistry and rheology, the morphology and mechanical performance of the materials can be tuned to create tailored composites.

These recyclability concepts have been extended to All-Solid-State Lithium Batteries (ASSLBs). LLZO-based composites can be reprocessed into solid-state electrolytes after cycling[3], though material recovery is challenged by component separation. We developed interfacial polymer layers to enhance the recyclability of ASSLBs, utilizing the low temperatures of cold sintering[4].

Cold sintering paves the way for eco-friendly composites and offers solutions to recycling challenges in advanced, high-performance materials across multiple applications.

Reference:

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