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RECYCLABLE POLYOLEFIN-BASED MICRO-/NANO-LAYERED FILM/FOAM STRUCTURES WITH TUNABLE MECHANICAL AND THERMAL PROPERTIES

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ABSTRACT

Micro-/nano-layer (MNL) structured materials have demonstrated significant potential in enhancing mechanical properties and functional performance across various applications. In this work, we explore a highly recyclable film/foam alternating MNL system based on polyolefin/polyolefin pairs, aiming to achieve superior mechanical strength and thermal insulation while maintaining full recyclability. Unlike conventional multilayer packaging materials that contain multiple polymer components and pose significant recycling challenges, this system leverages the inherent compatibility of polyolefin layers, providing a sustainable approach for advanced lightweight structures.

The proposed MNL structure consists of alternating solid and foamed layers, where the solid layers act as barriers that confine cell growth within the foamed regions. This confinement effect enables precise control over cell morphology, facilitating optimized structural design to enhance both mechanical and thermal properties. By adjusting layer thickness, foaming conditions, and material pair combinations, we systematically tailor the structure to achieve an optimal balance between mechanical strength and thermal insulation. Additionally, the solid layers' confinement improves foam cell uniformity, potentially reducing defects and enhancing overall material performance.

To investigate the feasibility of this approach, we employ a combination of experimental and in-situ visualization techniques. Micro-tensile testing of the multilayered structure is conducted to assess mechanical behavior, while real-time foaming observations provide insights into cell nucleation, growth dynamics, and interfacial stability. Batch foaming studies are performed with selective foaming of one of the polyolefin layers, exploring different gradient configurations where one layer remains solid while the adjacent layer undergoes controlled foaming. The effects of these processing variations on mechanical reinforcement and thermal insulation efficiency are analyzed to establish structure-property relationships.

By developing a recyclable polyolefin-based MNL film/foam system with tunable mechanical and thermal properties, this study presents a novel pathway for advancing both performance and sustainability in polymer-based materials. The insights gained from this work contribute to the broader field of recyclable polymeric structures, paving the way for environmentally friendly alternatives to conventional multilayer packaging and insulation materials.