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Advanced materials are essential for boosting the fuel economy of modern automobiles, aerospace, semiconductor, and energy while maintaining safety and performance. For example, in the automotive industry, lightweight materials offer great potential for increasing vehicle safety and efficiency. A 10% reduction in vehicle weight can result in a 6%-8% fuel economy improvement. Therefore, tremendous efforts have been devoted to developing advanced structural materials featuring a combination of lightweight, improved stiffness/strength, and energy absorption.

Here we describe the in-plane compressive performance of a new type of hierarchical cellular structure created by replacing cell walls in regular honeycombs with triangular lattice configurations. The fabrication of this relatively complex material architecture with size features spanning from micrometer to centimeter is facilitated by the availability of commercial 3D printers. We apply to these hierarchical honeycombs a thermal treatment that facilitates the shape preservation and structural integrity of the structures under large compressive loading. The proposed hierarchical honeycombs exhibit a progressive failure mode, along with improved stiffness and energy absorption under uniaxial compression. High energy dissipation and shape integrity at large imposed strains (up to 60%) have also been observed in these hierarchical honeycombs under cyclic loading. Experimental and numerical studies suggest that these anomalous mechanical behaviors are attributed to the introduction of a structural hierarchy, intrinsically controlled by the cell wall slenderness of the triangular lattice and by the shape memory effect induced by the thermal and mechanical compressive treatment.

It should be pointed out that other advanced manufacturing techniques, such as two-photon lithography can also be employed to create hierarchical cellular solids at a smaller length scale and with a broad choice of materials. As such, the mechanical response of the as-fabricated multiscale hierarchical honeycombs under different conditions, such as low velocity impact and shock wave loadings, can be investigated accordingly. The findings in this work not only provide us a better understanding of the compressive response of a new type of cellular structures, but also offer new opportunities for the design of structured materials capable of achieving extreme and customizable energy absorption property that can be of particular interest for applications in automotive, aerospace, semiconductor, and energy.