Remarkable stiffness enhancement in multilayered honeycombs obtained through periodic variations in Poisson's ratio

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Periodic variation in material properties is a construction principle often seen in biological and man-made materials. Common examples include lamellar bone, nacre and synthetic laminates. The mechanical response of layered structures with periodic Young's modulus is well understood with the elastic properties bounded by conventional rule of mixtures and with the enhancement in fracture toughness resulting from shielding effects to the crack tip. Less is known on the behavior of materials with periodic variations in Poisson's ratio. Such structures are unusual in nature and difficult to obtain by traditional manufacturing techniques, where the fine tuning of the Poisson's ratio is challenging. Introducing cellular architecture into solid materials is a powerful strategy to tailor mechanical properties without changing material chemistry. Here, we exploit cellular architectures to design multilayered honeycombs with periodic variation in Poisson's ratio. Starting from a regular isotropic two-dimensional honeycomb, we generated different periodic lattices by changing the tilting angle of the oblique beams. Angles higher than 90 degrees lead to the so-called reentrant cells, exhibiting negative Poisson's ratio. The elastic matrix of the lattices was computed based on micromechanical modeling. Multilayered cellular materials were then obtained by a periodic stacking of layers with negative and positive Poisson's ratio honeycombs. The apparent elastic properties of generated structures were simulated under different loading conditions by beam finite element analysis. Alternating layers of honeycombs having Poisson's ratio of 1 and -1, with the same Young's modulus, led to an almost 4 fold increase in the apparent stiffness with respect to the individual layers. A further increase of the Poisson's ratio mismatch (2.4 and -2.4) amplified the apparent stiffness by 8.5 folds. Ongoing work focuses on the fabrication of such multilayered honeycombs by three-dimensional polymer printing to assess the failure and post-failure mechanical response.