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Metamaterials with negative Poisson's ratio and non-positive thermal expansion

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Abstract

Four metallic metamaterials with tailorable mechanical properties are designed using bi-material star-shaped re-entrant planar lattice structures, which do not involve pins, adhesive, welding or pressure-fit joints and can be fabricated through laser-based additive manufacturing. Three length parameters, one angle parameter and three material combinations are used as adjustable design parameters to explore structure-property relations. For each of the four designed metamaterials, the effects of the design parameters on the Poisson's ratio (PR), coefficient of thermal expansion (CTE), Young's modulus and relative density are systematically investigated using unit cell-based finite element simulations that incorporate periodic boundary conditions. It is found that the bi-material lattice structures can be tailored to obtain 3-D printable metallic metamaterials with positive, near-zero or negative PR and CTE together with an uncompromised Young's modulus. In particular, it is shown that metamaterial # 1 can exhibit both a negative PR and a non-positive CTE simultaneously. These metallic metamaterials can find applications in structures or devices such as antennas and precision instruments to reduce thermomechanical stresses and extend service lives.

Keywords: Metamaterial, re-entrant lattice structure, auxetic material, near-zero thermal expansion, negative Poisson's ratio, additive manufacturing, Young's modulus, relative density

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