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Routes to Program Thermal Expansion in Three-dimensional Lattices Built from Tetrahedral Building Blocks

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Thermal expansion can be problematic in manifold applications that require thermal stability, yet it can also be purposely exploited to meet specific directional requirements of thermal deformation. Opportunities to tailor thermal expansion in architected materials exist [1-5], but 3D design options that are stiff and provide full directional authority on thermal expansion are currently limited by the structural characteristics of existing concepts. In this work, we report routes to systematically engineer thermally responsive 3D lattices that are built from dual-material tetrahedral units that are stiff and strong. Drawing from concepts of vector analysis, crystallography, and tessellation, a scheme is presented for three-dimensional lattices to program desired magnitude and spatial directionality of thermal expansion, such as unidirectional, transverse isotropic, or isotropic. Demonstrations include theoretical, computational and experimental studies on thermal expansion and mechanical properties of nine representative concepts, from tetrahedral building blocks to compound unit cells that can tessellate structurally efficient lattices with tunable magnitude and prescribed directionality of thermal expansion.

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