Additive Manufacturing and Architected Materials: New Processes and Materials

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Material properties are governed by the chemical composition and spatial arrangement of constituent elements at multiple length-scales. This fundamentally limits material properties with respect to each other creating trade-offs when selecting materials for specific applications. For example, strength and density are inherently linked so that, in general, the more dense the material, the stronger it is in bulk form. We are combining inverse design methods such as topology optimization, with advanced additive micro- and nanomanufacturing techniques to create new material systems with previously unachievable property combinations – mechanical metamaterials. The performance of these materials is fundamentally controlled by geometry at multiple length-scales, from the nano- to the macroscale, rather than chemical composition alone. We have demonstrated designer properties of these mechanical metamaterials in polymers, metals, ceramics and combinations thereof. Properties include ultra-stiff lightweight materials [1], negative stiffness [2], and negative thermal expansion [3] to name a few, as well as functional properties such electrical [4], optical [5], and even chemical responses. Recently, we have also demonstrated metamaterials which respond to external stimuli; namely magnetic fields [6].

We have primarily utilized our custom developed additive micro- and nano- additive manufacturing techniques to create these structures and materials. These include projection microstereolithography (PμSL), direct ink writing (DIW), and electrophoretic deposition (EPD). I will also touch on new advanced concepts such as volumetric additive manufacturing (VAM) [7], computed axial lithography (CAL) [8], parallel two-photon polymerization, and diode-based additive manufacturing (DiAM) [9] as well as new materials including graphene aerogel [10] and nanoporous gold [11].

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Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.

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