

Materials by Design: 3-Dimensional Architected Nanostructured Meta-Materials

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Creation of extremely strong yet ultra-light materials can be achieved by capitalizing on the hierarchical design of 3-dimensional nano-architectures. Such structural meta-materials exhibit superior thermomechanical properties at extremely low mass densities (lighter than aerogels), making these solid foams ideal for many scientific and technological applications. The dominant deformation mechanisms in such “meta-materials”, where individual constituent size (nanometers to microns) is comparable to the characteristic microstructural length scale of the constituent solid, are essentially unknown. To harness the lucrative properties of 3-dimensional hierarchical nanostructures, it is critical to assess mechanical properties at each relevant scale while capturing the overall structural complexity.

We present the fabrication of 3-dimensional nano-lattices whose constituents vary in size from several nanometers to tens of microns to millimeters. We discuss the deformation and mechanical properties of a range of nano-sized solids with different microstructures deformed in an *in-situ* nanomechanical instrument. Attention is focused on the interplay between the internal critical microstructural length scale of materials and their external limitations in revealing the physical mechanisms which govern the mechanical deformation, where *competing material- and structure-induced size effects* drive overall properties.

We focus on the deformation and failure in metallic, ceramic, and glassy nano structures and discuss size effects in nanomaterials in the framework of mechanics and physics of defects. Specific discussion topics include: fabrication and characterization of hierarchical 3-dimensional architected meta-materials for applications in biomedical devices, ultra lightweight batteries, and damage-tolerant cellular solids, nano-mechanical experiments, flaw sensitivity in fracture of nano structures.