Abstract

The objective of proposed work is to develop the scientific and engineering foundations for 3-dimensional nano-architected meta-materials that are simultaneously lightweight, damage tolerant, and thermally insulating. A successful execution will shift the paradigm of material creation towards more of a "materials by design" approach and will enable transformative advances in the areas of lightweight damage-tolerant materials, structural mechanics, device integration, photovoltaics, energy storage, and electronic devices.

Some of the most compelling opportunities pertain to the integration of ultra light weight and superior damage tolerance offered by nanolattices with other properties, like thermal transport and light trapping, in a single meta-material, which do not currently exist. These nanolattices represent a class of new "meta-materials" that can utilize the optimized nanometer-sized induced material properties, high surface area and 3D architectures, to enable distinct departure from existing material systems. It is the combination of bio-inspired hierarchical design and nanoscale dimensions of the solid that enable de-coupling historically linked properties like strength and density through architectural control. Proposed methodology enables the fabrication of multiple small-scale samples that combine previously unattainable properties – for example, simultaneous extreme light weight and damage tolerance combined with high strength, exceptional thermal insulation (or conductivity) and energy absorption.

The proposed tasks include (1) development of new classes of 3-dimensional nano-architected meta-materials and devices compatible with them, (2) experimental and theoretical investigation of mechanics and microstructure of specific geometries and materials that elicit resilience, resistance to damage, and high strength, at extremely light weight (<0.01% relative density) even when substantially deformed, and (3) integration schemes for developing a scalable process to manufacture these 3D nano-architected meta-materials and functional systems. A successful program will yield not only new fundamental knowledge in materials science and engineering mechanics but will also guide practical design strategies for new classes of ultralightweight, damage tolerant materials.