Hierarchical 3-D Nano-Architectures for Biomimetics, Batteries, and Lightweight Structural Materials

Abstract:

Creation of extremely strong yet ultra-light materials can be achieved by capitalizing on the hierarchical design of 3-dimensional nano-architectures. Such structural metamaterials 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.

Presenter Bio:

Greer received her S.B. degree in Chemical Engineering with a minor in Advanced Music Performance from MIT in 1997 and a Ph.D. degree in Materials Science and Engineering from Stanford University. She has also worked as an integration engineer at Intel Corporation (2000-03) and was a post-doctoral fellow at the Palo Alto Research Center, PARC (2005-07). Julia joined the Division of Engineering and Applied Sciences of California Institute of Technology (Caltech) in 2007 and has appointments in Materials Science, Mechanical Engineering, and Medical Engineering departments. Greer was recognized as a Young Global Leader by the World Economic Forum (2014) and is a recipient of the Nano Letters Young Investigator Lectureship (2013), Society of Engineering Science Young Investigator Award (2013), TMS Early Career Faculty award (2013), the inaugural NASA Early Career Faculty award (2012), Popular Mechanics Breakthrough Award (2012), Sia Nemat-Nasser ASME Early Career Award (2011), DOE Early Career award (2011), WTN’s World Technology Award in Materials (2010), TMS’s Young Leaders award in structural materials division (2010), DARPA’s Young Faculty Award (2009), Technology Review’s Top Young Innovator Under 35 award, TR-35, (2008), NSF’s CAREER Award (2007). Greer serves as an Associated Editor of Nano Letters and on the Board of Reviewing Editors for Science.