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

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Creation of extremely strong and simultaneously ultra lightweight materials can be achieved by incorporating architecture into material design. We fabricate 3-dimensional nano-architectures whose constituents vary in size from several nanometers to tens of microns to millimeters and centimeters, that exhibit superior thermal, photonic, electrochemical, and mechanical properties at extremely low mass densities (lighter than aerogels), rendering them ideal for many scientific and technological applications. The dominant properties of such meta-materials, where individual constituent size (atoms to nanometers to microns) is comparable to the characteristic microstructural length scale of the constituent solid, are largely unknown because of their multi-scale nature. To harness the beneficial properties of 3-dimensional nano-architected meta-materials, it is critical to assess properties at each relevant scale while capturing the overall structural complexity.

We discuss the deformation, as well as mechanical, biochemical, electrochemical, and photonic properties of nanolattices made of different materials and with a range of different atomic-level microstructures. Attention is focused on the interplay between the internal critical microstructural length scale of materials and their external limitations in revealing the physical mechanisms that govern these properties, where *competing material- and structure-induced size effects* drive overall response. Specific discussion topics include: fabrication and characterization of (often hierarchical) 3-dimensional nano-architected meta-materials for applications in chemical and biological devices, ultra lightweight energy storage systems, damage-tolerant fabrics, and photonic crystals.

Some Relevant publications:

1. L. R. Meza, S. Das, J. R. Greer "Strong, Lightweight and Recoverable Three-Dimensional Ceramic Nanolattices" ***Science* 345**, 1322-1326 (2014)
2. D.W. Yee, M.D. Schulz, R.H. Grubbs, & J.R. Greer "Functionalized 3D Architected Materials via Thiol-Michael Addition and Two-Photon Lithography" ***Advanced Materials*** doi: 10.1002/adma.201605293 (2017)
3. J.R. Greer "Materials by design: Using architecture and nanomaterial size effects to attain unexplored properties." *Nat'l Acad. of Engineering's* ***Bridge*** 45(4) (2015)
4. L. Meza, et al., J.R. Greer "Hierarchy in 3-D Architected Meta-Materials Brings Resilience" ***Proc of the Nat'l Academy of Sciences*** 112 (37), 11502 (2015)
5. X. Xia, C. V. Di Leo, X. W. Gu, A. Lozano, J. R. Greer "In Situ Lithiation–Delithiation of Mechanically Robust Cu–Si Core–Shell Nanolattices in a Scanning Electron Microscope" ***ACS Energy Letters* 1**, 492–499 (2016)
6. V. Chernow, H. Alaeian, J. Dionne, J.R. Greer ""Polymer Nanolattices as Mechanically Tunable 3-Dimensional Photonic Crystals" ***Appl. Phys. Lett* 107**, 101905 (2015)
7. C. Xu, Z. Ahmad, A. Aryanfar, V. Viswanathan, & J.R. Greer "Enhanced strength and temperature dependence of mechanical properties of Li at small scales and its implications for Li metal anodes" ***Proc Nat'l Acad Sciences of the USA* 114** (1), 57-61 (2016)