THE MATERIALS SCIENCE AND ENGINEERING DEPARTMENT
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Exceptional mechanical properties of additively manufactured nano-architected materials with complex topologies

Architected materials, i.e. cellular solids with optimally designed unit cell topologies, have been investigated for decades for their ability to provide tunable combinations of mechanical properties at low density. Historically, the challenges associated with fabricating these materials have resulted in relatively simple 2D and 3D architectures, with the mechanically efficient octet lattice by far the most heavily investigated topology. This is rapidly changing, as recent progress in additive manufacturing technologies has dramatically expanded the design space, enabling materials designers to think more creatively about optimal topologies. In this presentation, we'll discuss three novel topologies with intriguing mechanical properties: (i) cube-octet plate lattices with unprecedented specific stiffness and strength, (ii) spinodal shell lattices with excellent damage tolerance and potential for self-assembly, and (iii) tensegrity truss lattices with delocalized deformation mechanisms. All topologies are fabricated by two-photon polymerization Direct Laser Writing (2pp-DLW), an additive manufacturing technology enabling nanoscale resolution and unique topological complexity. Subsequently, plate and shell lattices are pyrolyzed, resulting in ceramic nano-architected materials with feature sizes of the order of 100nm. At this scale, existing cracks are too small to induce brittle failure and the theoretical strength of the base material (of the order of a tenth of the Young's modulus) can be achieved. We show that the combination of optimally designed unconventional topologies and unique nanoscale size effects on the constituent material result in complex nano-architected materials with unique combinations of properties. Finally, opportunities for scalability are discussed.

Lorenzo Valdevit received his MS degree (Laurea) in Materials Engineering from the University of Trieste, Italy (in 2000) and his PhD degree in Mechanical and Aerospace Engineering from Princeton University (in 2005). He worked as an intern at the IBM T.J. Watson Research Center and as a post-doctoral scholar at the University of California, Santa Barbara. He joined the faculty in the Mechanical and Aerospace Engineering Department at the University of California, Irvine in 2007. In 2018, he moved his appointment to the newly established Department of Materials Science and Engineering, where is currently a professor. He is serving as the inaugural director of the Institute for Design and Manufacturing Innovation in the School of Engineering. He is a Fellow of the American Society of Mechanical Engineers (ASME), the recipient of the 2007 Faculty Award from IBM Corporation, the 2012 Popular Mechanics Breakthrough Award and the 2018 Outstanding Faculty Service award from the School of Engineering at UCI. His primary research goal is the modeling, optimal design, additive manufacturing and experimental characterization of architected materials with superior combination of properties.

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