Optical and Mechanical Metamaterials

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The ability to engineer the properties of high-performance materials is critical for applications ranging from high-efficiency energy production and storage, to advanced medical imaging and therapeutics. The principle of "metamaterials" refers to the design of composites whose properties derive as much from their structure as from their composition. Metamaterials have energized many materials engineering disciplines, leading not only to the discovery of a powerful "toolbox" of new design methods, but to an expansion in our fundamental understanding of the physics of materials. Metamaterials have been particularly impactful in the fields of mechanics and photonics, where a number of conventionally accepted bounds on material performance have been re-evaluated, and a great array of surprising, and often useful, properties have been discovered.

For example, optical metamaterials have enabled control over both the electric *and* magnetic fields of light, so that permittivities and permeabilities can be precisely tuned throughout positive, negative, and near-zero values. Though careful design of subwavelength 'meta-atoms', optical metamaterials have enabled negative refraction, optical lensing below the diffraction limit of light and invisibility cloaking. Likewise, based on their micron–to–submicron structure, mechanical metamaterials exhibit extraordinary responses to applied forces, including negative bulk moduli, negative Poisson's ratios, and negative mass densities. Such effects have been used to create solids that behave like liquids and ultra-light, low-density materials with unprecedented strength.

This session will highlight the impact of recent scientific advances in metamaterials, including fundamental breakthroughs and technological relevance. Speakers will discuss a breadth of topics including metallic and ceramic mechanical metamaterials, compliant mechanisms, new plasmonic and resonant dielectric optical metamaterials and metasurfaces, acoustic metamaterials, microelectromechanical devices, and advanced nano and micro-scale manufacturing of large-area metamaterials.

The session will begin with a talk by Dr. Julia Greer (California Institute of Technology), who creates and studies advanced materials that derive extraordinary strength from three-dimensional architecture and microstructure. She also studies recoverable mechanical deformation in compliant nanomaterials. By constructing nanolattices of a wide variety of constituents from ceramics to metals, semiconductors, and glasses, Dr. Greer's research enables new applications in thermomechanics and impacts such disparate fields as ultralightweight batteries and biomedical devices. The second speaker, Dr. Chris Spadaccini (Laurence Livermore National Lab), will talk about the development of engineering materials with remarkably light weight and ultra-high stiffness. Dr. Spadaccini will also describe the relationship between nano-structure and designer properties such as negative thermal expansion and negative stiffness. Next, Dr. Andrea Alu (University of Texas, Austin) will discuss metamaterial-based design engineering. Dr. Alu's research highlights the connection between microscopic structural properties of metamaterials, like symmetry and shape, on their macroscopic response, and his work focuses in particular on creating new useful devices that would not be possible with conventional materials, such as one-way antennas, “invisibility cloaks” that work over a wide spectral bandwidth, and acoustic circulators. The final speaker, Dr. Alexandra Boltasseva (Purdue University), will speak about optical and infrared metamaterials, and about metamaterial-enabled devices that could revolutionize optical technologies in communications, photovoltaics, and thermal radiation management. One of Dr. Boltasseva’s research focus areas is the incorporation of high-temperature and functional materials as constituents of metamaterials. This is a critical frontier at the current time, as optical metamaterials transition from the laboratory into specific real-world applications with challenging requirements.