



Editorial for the focus issue on “Frontiers of Mechanical Metamaterials”



The notion of a *metamaterial* has emerged nearly two decades ago and continues to fuel the imagination of researchers from across the physical sciences and engineering disciplines. Nearly three decades earlier, the concept of a *composite* had a similar effect—one at the time could only imagine the wealth of possibilities when mixing two or more constituent materials, each with its unique properties, to obtain a new engineered material that effectively captures the best traits of each component when viewed alone. Metamaterials represent the next big step in this direction, except now it is the internal structure, rather than the composition, that is engineered. The outcome is a net property, or a series of properties, that are not only superior to the sum of the parts, but possibly exceed what is naturally conceivable.

Metamaterials started in the realm of electromagnetics and acoustics, however more recently it expanded to a wider range of disciplines including mechanics of materials and the thermal sciences. In this focus issue of the journal *Extreme Mechanics Letters*, we have gathered fourteen peer-reviewed papers that provide an ensemble of some of the most recent research themes in the field, focusing on “extreme” behavior in acoustic and elastic waves, mechanical response, and thermoelasticity. With this selection, we hope to provide to the reader a taste of some of the latest advances in this broad subfield of metamaterials that has been growing rapidly and now commonly described as *mechanical metamaterials*.

The collection consists of two groups of papers. The first group starts with new explorations of phononic crystals and locally resonant metamaterials. Zhang et al. examine pipes with periodic material patterning in the axial and radial directions, and Claeys et al. demonstrate the effects of adding locally resonant arms to plates and ducts. Barnwell et al. demonstrate tunable Bragg gaps by engineered pre-strain; Krushynska et al. study two-dimensional and three-dimensional resonant structures featuring internal bridges; and Yu et al. utilize dielectrics for tuning of hybridization gaps. In another set of papers, realization of extreme dissipation is pursued via embedded negative stiffness inclusions (Chronopoulos and Antoniadis) and inclusions with stiffness characteristics designed to attenuate and trap broadband vibration/acoustic energy (Harne et al.). Granular media is also featured. Zheng et al. propose spherical beads arranged in a graphene-like lattice and show how rotational modes in this system bring rise to slow edge waves. Allein et al., on their

part, demonstrate zero-group velocity modes in chains of beads activated by magnetic elements. This group of papers concludes with a method of dynamic homogenization demonstrating that the effective properties of an acoustic metamaterial are resonant and nonlocal (Ponge et al.).

The second group of papers examines extreme mechanical and thermoelastic properties. Tang and Yin explore hierarchical kirigami configurations for high stretch and compressibility, and do Rosário et al. propose inverse opal structures for high stiffness and strength. Watts and Tortorelli investigate the optimality of thermal expansion bounds in three-dimensional unit cells using topology optimization, and Ha et al. design triangular cell lattices composed of bi-material curved ribs which with appropriate tuning are shown to exhibit positive, negative, or zero thermal expansion.

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