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AUXETIC METAMATERIALS: FROM DESIGN TO PERFORMANCE

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ABSTRACT

Architected metamaterials achieve tailored mechanical performance via the geometry and hierarchy of their microstructure. Auxetic architectures are a prominent example, combining negative effective Poisson's ratios with unusual deformation modes, high specific energy absorption, and tunable stiffness. For load-bearing applications, however, their decisive behavior often emerges beyond the elastic regime, where material nonlinearity interacts with geometric instability, contact, localization, damage, and fracture across several length scales.

This Invited Session addresses computational methods for the nonlinear, inelastic, and failure-dominated response of auxetic and architected metamaterials, with particular emphasis on the link between microstructural design and structural performance. Contributions are invited on finite-strain elastoplasticity and viscoplasticity, acoustic performance, instability and pattern transformation, damage and fracture, dynamics and vibration including high-rate and impact response, multiscale homogenization and generalized continua, and coupled multiphysics phenomena.

The session also welcomes topology and shape optimization, sensitivity analysis, uncertainty quantification, model reduction, and data-driven or physics-informed surrogate models for efficient exploration of large design spaces. Digital shadows and digital-twin concepts for model updating, prediction, and reliability assessment are likewise within scope. A central objective is to connect high-fidelity simulation with fabrication and experimental validation. Relevant topics therefore include additive and advanced manufacturing, process- and defect-informed modelling, digital image correlation, micro-CT-based characterization, and inverse identification.

Application-oriented studies may address lightweight civil, flight, and space structures, vibration and wave control, impact protection, energy absorption, structural sensing, and energy harvesting. By bringing together computational mechanics, materials science, optimization, manufacturing, and experiments, the session aims to clarify how nonlinear mechanisms can be deliberately exploited rather than merely tolerated, enabling robust and verifiable architected metamaterial structures from unit-cell design to component scale.