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Self-sensing architected materials

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Integrating self-sensing materials into future applications necessitates developing advanced multiscale multiphysics predictive models. This study introduces an experimentally informed predictive framework for autonomous sensing architected materials, combining theoretical and computational methodologies. By incorporating stress-dependent electrical resistivity through anisotropic piezoresistive constitutive effects, alongside considering material, geometric, and contact nonlinearities, the proposed multiscale model captures the architecture-dependent piezoresistive responses of lattice composites produced via additive manufacturing of polyetherimide (PEI)/carbon nanotube (CNT) nanoengineered feedstock. The PEI/CNT composite exhibits exceptional strength (105 MPa), stiffness (3368 MPa), and strain sensitivity (gauge factor ≈ 13), translating into remarkable piezoresistive characteristics for the PEI/CNT lattice composites (gauge factor ≈ 3 to 11). This multiscale finite element model predicts both macroscopic piezoresistive responses and the influence of architectural and topological variations on electric current paths, validated via infrared thermography analysis. Additionally, an Ashby chart for the gauge factor of PEI/CNT lattice composites suggests their prediction through a scaling law similar to mechanical properties, underscoring the tunable strain and damage sensitivity of these materials. The combined experimental, theoretical, and numerical findings offer critical insights into optimising piezoresistive composites through architected design, with profound implications for smart orthopedics, structural health monitoring, sensors, batteries, and other multifunctional applications.

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