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Symposium Contributions

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Fracture Toughness of Hierarchical, Low Density Architected Metamaterials

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Fracture Toughness of Hierarchical, Low Density Architected Metamaterials

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Rapid progress in additive manufacturing methods has led to the creation of a new class of ultralight, stiff and strong 3D architected metamaterials comprised of a network of hierarchical, stretch-dominated, micro-scale unit cells. The performance of these micro-architected metamaterials, spanning across multiple length scales, will ultimately be limited by their tolerance to damage and defects, yet an investigation of their fracture toughness has remained elusive.
Here, we provide the first experimental observations of different crack initiation modes activated by mode-I loading of notched low density, hierarchical metamaterials. We find that, through hierarchical micro-architected features, the low density, stretch-dominated metamaterials can achieve simultaneously higher fracture toughness and strength: properties that are usually mutually exclusive. Numerical and scaling relationships are also reported that accurately capture the measured fracture toughness and strength values. These are then used to develop design maps for the optimal hierarchical architectures as functions of the density of the metamaterial and failure strain of the parent material.