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PROCEEDINGS

Multi-Shape Memory Mechanical Metamaterials

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ABSTRACT

Stimuli-responsive materials can alter their physicochemical properties, e.g., shape, color, or stiffness, upon exposure to an external trigger, e.g., heat, light, or humidity, exhibiting environmental adaptability. Among them, shape memory materials are limited by their multi-shape memory effect and the complex thermomechanical programming. In this work, we harness the distinct temperature-dependent elastic moduli of two 3D-printable polymers, that do not rely upon their intrinsic shape memory effect and compositional alteration to generate robust and simplified multi-shape memory responses in a variety of stimuli-responsive mechanical metamaterials, bypassing the typical intricate programming of conventional multi-shape memory polymers. This was achieved through the modular arrangement of bimaterial building blocks, each exhibiting distinct snap-through deformation modes and instability transition temperatures. We investigate this stability transition mechanism through a comprehensive approach, including theoretical models, numerical simulations, and thermomechanical experiments. Our responsive metamaterials exhibit remarkable features, including step-by-step multistability, multiple deformation modes, adjustable stiffness, multi-shape memory, and swift recovery. We demonstrate their multifunctional applications in reusable energy absorbing, fire protection sensors, and self-sensing grippers. Importantly, our approach is versatile, applicable to diverse patterns and instabilities, and adaptable to different materials. By harnessing bimaterials with distinct thermomechanical or chemicomechanical behaviors, multi-shape memory metamaterials responsive to various external stimuli, such as temperature, light, or moisture, can be created. This paves the way for a wide range of multifunctional applications, including adaptive morphing equipment, self-healing and self-assembly devices, self-powered sensors and actuators, and reconfigurable soft robots.

KEYWORDS

Stimuli-responsive metamaterials; multi-shape memory effect; structural stability; tunable stiffness; thermomechanical response

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