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Environmentally Triggered Instabilities in Origami Structures[1]

PHIL BUSKOHL, BEN TREML, ANDREW GILLMAN, RICHARD VAIA, Air Force Research Laboratory — Mechanically adaptive films and 3D structures that respond to environmental stimuli (light, heat, humidity) show promise as next-generation materials in devices, sensors, and regulators. The interplay between a material's response to an external environmental field and the deformation presents an opportunity for local material design to achieve targeted actuation. While response rates can be fast, the associated strains are often small and limit motion. To amplify the mechanical response, origami fold patterns are designed and embedded into environmentally responsive thin films. Design of these origami structures is accomplished through development of a topology optimization framework that discovers optimal fold patterns that achieve targeted metastable equilibrium positions through environmentally induced instabilities. These computationally designed patterns are experimentally realized through additive manufacturing of composite structures that exhibit active and inactive zones. These concepts are demonstrated for hygroscopic polymers subject to humidity gradient fields to illustrate how environmentally responsive materials with local patterning can amplify the mechanical response and enable enhanced functionalization for remote, autonomous locomotion.

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