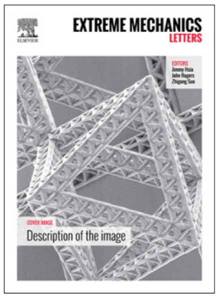
Accepted Manuscript



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PII: S2352-4316(17)30074-3
DOI: http://dx.doi.org/10.1016/j.eml.2017.08.001
Reference: EML 299

To appear in: *Extreme Mechanics Letters*

Received date : 19 May 2017
Revised date : 31 July 2017
Accepted date : 1 August 2017

Please cite this article as: J. Guo, T. Shroff, C. Yoon, J. Liu, J.C. Breger, D.H. Gracias, T.D. Nguyen, Bidirectional and biaxial curving of thermoresponsive bilayer plates with soft and stiff segments, *Extreme Mechanics Letters* (2017), http://dx.doi.org/10.1016/j.eml.2017.08.001

Bidirectional and Biaxial Curving of Thermoresponsive Bilayer Plates with Soft and Stiff Segments

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Abstract

Curved bilayer plates with soft and stiff segments are widely observed in nature, such as plant cell walls, insect exoskeletons and reptile skins. We report an unusual biaxial and bidirectional bending of microfabricated bilayer plates composed of a swellable, photopolymerized poly(N-isopropylacrylamide-co-acrylic acid) (pNIPAM-AAc) layer and a regular array of SU-8, a stiff, non-swellable epoxy. Hydrogels such as pNIPAM-AAc exhibit large and reversible swelling in an aqueous solvent in response to a temperature change through the lower critical solution temperature (LCST). The stimuli responsive behavior was harnessed in the composite structure containing materials with mismatched swelling and elastic properties to produce actuation and mechanical motion. The structure undergoes reversible bending along two different axes in response to a temperature cycle through the LCST. Cooling the patterned bilayer structure leads to bending upwards about one axis, while heating leads to bending downwards about a different axis 90^o from the first. To understand the mechanism of this biaxial bending behavior, we developed a finite element model of the patterned bilayer structure. A constitutive model that combined the hyperelastic and swelling behavior was used to describe the thermoresponsive hydrogel. The model was applied to investigate the effects of geometric factors of patterned bilayer on the bending behavior of the composite structure.

Keywords: Self-folding, finite element simulation