Nature is masterful at using limited components and basic driving forces to achieve complex tasks, such as high-power movement and multi-structure assembly, across a broad range of size scales. The materials that enable these achievements often rely upon the integration of phases that allow for internal transport, elastic energy storage, system protecting dissipation, and tunable sensitivity to interfacial interactions. Accordingly, polymer gels, which combine liquid phases with shear-sustaining macromolecular network structures, offer a robust materials platform for transferring lessons from nature into synthetic engineered devices. Here, we describe two examples from our research group of how to take advantage of mesoscale structural asymmetry, mechanics, liquid transport, and interfacial interactions to achieve new engineered capabilities. The first example takes inspiration from multiple examples in nature, including mantis shrimp and trap-jaw ants, that use Latch-Mediated Spring Actuation (LaMSA) to achieve high power, impulsive movements. We demonstrate how transient metastable deformations associated with swelling and deswelling of a polymer gel can be exploited to generate mechanical bi-stability, giving rise to multiple, self-repeating, snap-through movements. We introduce models to quantitatively describe these mechanisms and harness them to develop autonomous jumping devices. In a related manner, the second example describes the use of structural asymmetry to mediate swelling/deswelling processes and elastic restoring forces to control the motion and assembly of mesoscale polymer gel ribbons. Collectively, both examples provide new insight into how polymer gel properties, related to elasticity, diffusion, and interfacial forces, can combine with purposeful structural design to yield complex tasks, which can be used in the development of microscale robots and new adaptable composite materials.

BIOGRAPHY

Alfred J. Crosby is a Professor in the Polymer Science & Engineering Department at the University of Massachusetts Amherst and Co-Director of the Center for Evolutionary Materials. His research interests lie generally in bio-inspired materials mechanics, especially topics including adhesion, nanoparticle assemblies, gels, thin films, fracture, hierarchical materials, and elastic instabilities. Al received his B.S. in Civil Engineering and Applied Mechanics from the University of Virginia and his Ph.D. in Materials Science & Engineering from Northwestern University. He was an NRC Postdoctoral Fellow at NIST in the Polymers Division from 2000-2002 before joining the faculty at UMass Amherst in 2002. He has received numerous awards, including being a Fellow of the American Physical Society and the National Academy of Inventors, and his research has been covered extensively in the popular media. He serves as advisor on several editorial boards and trade organizations and is an Associate Editor for Soft Matter.

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