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Abstract

Multiphysics Modeling of Ionic Polymer Metal Composites, with Application in Underwater Sensing †

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Ionic polymer metal composites (IPMCs) are a novel class of soft active materials that are receiving considerable attention as sensors and actuators. For instance, IPMCs have found application in biomimetic actuators for underwater propulsion and manipulation. Moreover, they have been utilized as flow, touch, and force sensors and have been integrated in several fluid energy harvesting devices. IPMCs have been shown to produce large mechanical deformations in response to a modest voltage applied across their electrodes, and, conversely, to generate a measurable voltage across their electrodes when subjected to an imposed mechanical deformation. In this talk, we present a novel physics-based modeling approach developed to describe the chemoelectromechanical behavior of IPMCs and, especially, resolve the complex interface phenomena taking place in the vicinity of the electrodes. The chemoelectromechanical constitutive behavior is obtained from a Helmholtz free energy density, which accounts for mechanical stretching, ion mixing, and electric polarization. Structural modeling and perturbation theory are leveraged to establish tractable reduced order models. We focus on sensing and present a few case studies spanning base excitation, impulsive loading from an impinging vortex ring, and impact on the free surface of a quiescent fluid. Analytical insight on the mechanics of the coupled fluid structure problem is used to interpret experimental results and provide design guidelines for sensors based on active compliant materials in fluids.