Multiphysics modeling of electroactive polymer composites: A multiscale approach

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Electroactive polymers (EAPs) are a class of materials that demonstrate low-moduli, high strain capabilities, and ability to change their shape when stimulated by an electric field. Owing to their capability to undergo large deformation in response to the external stimuli, EAPs are considered 'smart materials'. In addition, EAPs have been nominated to be applicable in number of fields such as robotics, optics, acoustics and biomimetics. However, a high driving electric field is required for actuating the isotropic electric EAPs that may cause electromechanical instability and/or electric breakdown. This poor electro-mechanical coupling is attributed to the fact that the dielectric constant and flexibility in a polymer have an inverse relationship. Promising experimental works suggest that this limitation may be overcome by making electroactive polymer composites (EAPCs), which are flexible and have a high dielectric modulus [1].

With regards to the computational modeling of EAPs, a numerical scheme has been developed using a reduced mixed finite-element formulation for simulating the nonlinear response of isotropic EAPs. With regards to computational homogenization of coupled problems, an FE^2 framework was developed for the simulation of elastic dielectric materials at finite strains in [3]. The microscopic boundary value problem has been defined on periodic RVEs, and the developed method has been applied for the simulation of bimorph actuator made of EAPCs with ceramic inclusions. Furthermore, the two-scale scheme has been implemented for studying the behavior of heterogeneous magneto-rheological elastomers in the presence and absence of free space in [4], and it was demonstrated that the macroscopic response of a magneto-rheological elastomer strongly depends on the morphology of the underlying microstructure.

The aim of this research work is to provide an understanding of the mechanisms governing the electromechanical response of EAPCs undergoing large deformations. To this end, a multiphysics computational framework including the electro-mechanical couplings and the viscoelastic properties of the constituents will be presented. Generally speaking, phenomenological models provide a mathematical tool for material response, however, they are limited in modelling composite materials. Therefore, a computational homogenization that is based on the mixed finite element formulation at both the macro-scale and micro-scale (i.e. MFE^2) will be presented.

References

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