Dielectric elastomer composites: A general closed-form solution in the small-deformation limit

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ABSTRACT

A solution for the overall electromechanical response of two-phase dielectric elastomer composites with (random or periodic) particulate microstructures is derived in the classical limit of small deformations and moderate electric fields. In this limit, the overall electromechanical response is characterized by three effective tensors: a fourth-order tensor describing the elasticity of the material, a second-order tensor describing its permittivity, and a fourth-order tensor describing its electrostrictive response. Closed-form formulas are derived for these effective tensors directly in terms of the corresponding tensors describing the electromechanical response of the underlying matrix and the particles, and the one- and two-point correlation functions describing the microstructure. This is accomplished by specializing a new iterative homogenization theory in finite electroelastostatics (Lopez-Pamies, 2014) to the case of elastic dielectrics with even coupling between the mechanical and electric fields and, subsequently, carrying out the pertinent asymptotic analysis. In addition, with the aim of gaining physical insight into the proposed solution and shedding light on recently reported experiments, specific results are examined and compared with full-field simulations for the case of dielectric elastomers filled with isotropic distributions of spherical particles.