

Finite Deformation Effects on the Mesoscale Mechanics of Liquid Crystal Elastomers

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Liquid crystal elastomers exhibit a number of fascinating material characteristics for artificial muscle and electro-optical applications. The constitutive behavior is strongly dependent on the interactions between liquid crystal domain structure evolution and polymer deformation during electrical or mechanical loading, application of heat, or exposure to light or chemical constituents. An analysis of the interactions between liquid crystals and elastomer networks is presented here using nonlinear continuum mechanics. Finite deformation of an elastomer is coupled to a set of liquid crystal configurational forces to describe elastomer deformation as a function of the effective liquid crystal molecular orientation (i.e., liquid crystal director). Spontaneous deformation is achieved using finite deformation theory without the use of any explicit phenomenological constants. A liquid crystal Landau energy is written in terms of the director n_i and compared to a Landau energy that uses the conventional second order traceless tensor $Q_{ij} = Q/2(3n_i n_j - \delta_{ij})$. Differences in spontaneous deformation are reviewed by coupling the liquid crystal energy functions with an elastomer hyperelastic energy function. The model is then implemented numerically using a nonlinear finite element phase field approach. Deformation for monodomain versus polydomain configurations are modeled and shape memory effects are discussed using thermoelasticity.