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PIEZOELECTRIC RESPONSE AND HOMOGENIZATION ESTIMATES IN TWO-PHASE FERROELECTRIC COMPOSITES WITH THERMAL STRESSES AND FREE CHARGES EFFECTS

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Abstract. The search for electro-deformable materials with specific combinations of properties not found in monolithic ferroceramics has motivated the development of an increasing variety of two-phase ferroceramic composites. These composites are typically made by sintering the constituent phases above the Curie temperature of the ferroceramic and subsequently cooling down the mixture to room temperature while applying electric fields to permanently pole the specimen. The influence of the second phase on the piezoelectric properties of the resulting composite depends intricately on its microstructural morphology. A wide range of micromechanical models have already been proposed to estimate such influence, but all proposals almost invariably treat the ferroceramic matrix of the poled composite as a stress-free dielectric phase with uniform piezoelectric coefficients. Due to material heterogeneity, however, strong spatial variations of the electric field can arise during the poling process which, in turn, can result in residual stresses and non-uniform piezoelectric coefficients within the permanently poled specimen. Furthermore, ferroelectric ceramics of technological interest are often wide-band-gap semiconductors rather than ideal dielectrics, in which case free charges can affect the domain switching process nontrivially. The purpose of this work is to theoretically assess free-charge and thermal effects in the piezoelectric properties of ferroceramic composites by means of homogenization theory. To that end, the electro-deformable behavior of the constituent phases is described via a stored energy density and a dissipation ,potential in accordance with the theory of generalized standard materials. An implicit time-discretization scheme is used to generate a variational representation of the overall response in terms of a single incremental potential. Estimates are then generated by constructing sequentially laminated microgeometries of particulate type whose overall incremental potential can be computed exactly. Because they are realizable, by construction, these estimates are guaranteed to conform with any material constraints, to satisfy all pertinent bounds. The estimates are used to assess the influence of metallic inclusions and microporosity on the piezoelectric coefficients of ferroceramics.