Derivation of a 3D magnetostrictive Preisach model for the simulation of magneto-electric composites

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ABSTRACT

In this contribution we focus on the magneto-electric (ME) coupling of multiferroic materials. They combine two ferroic characteristics and exhibit an interaction between magnetic and electric fields. This magneto-electric coupling can find applications in sensor technology or in electric field-controlled magnetic data storage devices [1]. Since most ME single-phase materials show an interaction between electric polarization and magnetization far below room temperature and therefore outside of a technical relevant temperature range, the manufacturing of two-phase composites, consisting of a ferroelectric matrix with magnetostrictive inclusions, becomes important. They generate the ME coupling at room temperature as a result of the interaction of their constituents. Hence, the ME coupling of composite materials significantly depends on the material behavior of both phases. In order to determine the effective properties with respect to both aspects, a multiscale finite element FE^2 homogenization approach is performed, which combines via a scale bridging the macro- and microscopic level. Therefore, the microscopic morphology is considered by using a representative volume element [2],[3]. Furthermore, the nonlinear properties of both phases are approximated with appropriate material models. On the one hand, the switching behavior of spontaneous polarizations of barium titanate unit cells are taken into account [4], which reproduces after a homogenization step the typical dielectric and butterfly hysteresis loops of the ferroelectric matrix material. On the other hand, the nonlinear remanent magnetizations of the magnetostrictive inclusions are described with a Preisach operator [5]. Both models affect the strain-induced coupling, such that we obtain a nonlinear behavior of the ME coefficient.

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