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Experimental Method and Constitutive Model of Electromagnetic Thin Films and Laminates under Multi-Field Loading

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ABSTRACT

Ferroelectrics, ferromagnetic, magnetoelectric thin films and composite laminates, have been widely used in modern industries, owing to their excellent coupling properties and quick responses. Their deformation behaviors under mechanical loading are affected considerably by an external electric or magnetic field. To provide a deep understanding of the intrinsic coupling properties, a novel electro-magneto-mechanical multi-field nanoindentation apparatus and a novel multi-field bulge-test instrument were designed and constructed. Characterization methods were also established for deformation of electromagnetic thin-films and laminates. The experimental results reveal the size-dependency of various mechanical properties in the electromagnetic materials, ranging from the Young's modulus, to the hardness. Notably, these properties can be well controlled by applying external electric/magnetic fields. Furthermore, a new size-dependent nonlinear constitutive model is developed for the magnetoelectric composite laminates to account for the coupling mechanisms under multi-field loading. The results are meaningful for the design and quality assessment of the electromagnetic functional devices.