A Free Energy model for Magneto-Mechanically Coupled NiMnGa Single Crystals

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Abstract

The paper presents a 1-D rate-dependent magneto-mechanical model for Ni-Mn-Ga single crystals. Motivated by previous models developed by the authors for conventional shape memory behavior and ferroelectricity, a constitutive Helmholtz free-energy landscape with strain and magnetization as order parameters has been constructed for a representative meso-scale lattice element. This landscape includes three paraboloidal energy wells representing two easy-axis martensite variants and one hard-axis variant relevant for the one-dimensional case.

The kinetics of the switching/phase transformation processes under combined mechanical stress and magnetic field loading follow from a system of evolution laws for the magnetic and martensitic phase fractions. They are based on the theory of thermally activated processes with transition probabilities derived from the energy barriers of the stress and field dependent Gibbs free energy landscape.

The phase fractions subsequently determine the macroscopic strain and magnetization of a sample of Ni-Mn-Ga by a standard averaging procedure. While the current version neglects local inhomogeneities and assumes "perfect" single crystal behavior, it reproduces several of the constitutive effects observed in single crystal Ni-Mn-Ga samples. Future work includes an extension to a full thermo-magneto-mechanical model accounting for the occurrence of austenite and inhomogeneity effects.