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NONLINEAR ELECTROCALORIC AND THERMOMECHANICAL EFFECTS IN FERROELECTRICS AND THEIR INFLUENCE ON DAMAGE AND CONSTITUTIVE BEHAVIOR

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Summary: Due to their special electromechanical properties, nowadays ferroelectric materials are widely used in many technical applications, mostly as actuators or sensors. Advantages compared to other smart devices are the extremely fast reaction times in a range of μm - ms and large actuation forces. Influences of temperature and heat flux due to electrocaloric and thermomechanical effects are mostly neglected in models, although they may have a non-negligible impact on issues like phase transitions, domain wall motion or reliability and lifetime.

In this paper, the theoretical background of a micromechanically and physically based constitutive model is presented. In addition to the nonlinear ferroelectric behavior and the evolution of damage in terms of microcrack growth, the model considers the mutual nonlinear coupling of thermal and electromechanical fields. Based on simplifying assumptions, analytical solutions to the electrocaloric effect are derived, more sophisticated problems require numerical solutions. The finite element method is used to solve complex boundary value problems. The calculations reveal switching processes in ferroelectrics and associated heating or cooling, enable the prediction of crack initiation e.g. at electrode tips in stack actuators and demonstrate the hysteresis characteristics of mechanical, electrical and thermal fields.