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Experimental approach for investigating polarization and strain switching dynamics in ferroelectric/ferroelastic materials

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An experimental method for simultaneous time-resolved measurements of polarization and strain was developed. The presence of multiple events during polarization switching of multiaxial ferroelectric/ferroelastic materials was revealed and characteristic times and activation fields were determined.

The polarization switching in ferroelectric single crystals is generally described by the Kolmogorov-Avrami-Ishibashi (KAI) model [1], while a more universal model was proposed for heterogeneous media, such as polycrystalline ceramics or polymers [2]. However, all these models assume one characteristic switching time or a distribution thereof, which is related to one characteristic switching event. While this seems to be sufficient to describe the polarization dynamics, the models fail to give an insight to the accompanying changes of the macroscopic strain. On the other hand, results from macroscopic strain and in-situ diffraction measurements clearly show that switching in most widely-used ferroelectrics, which are also ferroelastic, occurs by multiple steps [3]. A deeper understanding of the switching process could be achieved if the physical parameters that characterize the multiple switching events could be determined simultaneously.

The aim of this work was therefore to develope an experimental approach for simultaneous measurements of the time-dependence of the macroscopic polarization and strain over a broad time domain of six orders of magnitude using the pulse method. A high-voltage (HV) switch was combined with a large capacitor, providing a HV pulse rise time of 200 ns. The time-dependence of polarization and strain was characterized by a conventional Sawyer-Tower circuit and an optical displacement sensor, respectively. The setup was used to evaluate the switching dynamics of a series of tetragonal and rhombohedral $Pb(Zr,Ti)O_3$ compositions (Figure 1). A simple model is suggested, which allows us to extract a characteristic switching time, as well as a time distribution. The activation fields for multiple events can be determined from field-dependent measurements. The experimental determination of the switching parameters is an important requirement for a more complete description of the switching process in ferroelectric/ferroelastic materials and represents the basis for future theoretical calculations of the switching dynamics.

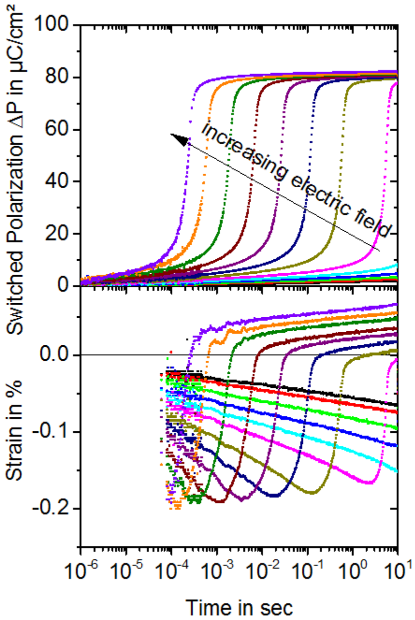

Figure 1. Simultaneous measurement of polarization and strain dynamics at various fields (0.5kV/mm–1.3kV/mm) for rhombohedral $Pb(Zr,Ti)O_3$ polycrystalline ceramic.

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2. Y. A. Genenko et al., *Adv. Funct. Mater.*, **22**, 2058 (2012)

3. J. E. Daniels et al., *J. Appl. Phys.*, **115**, 224104 (2014)