Nonlinear properties of hard and soft PZT ceramics

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Nonlinearity and hysteresis in piezoelectric ceramics have been intensively studied ever since the application potential of these materials had become evident. In the most widely used piezoelectric ceramics, based on Lead Titanate Zirconate (PZT) solid solutions, the properties are controlled by addition of various dopants and additives. For example, the acceptor and donor dopants are used to make the samples “hard” and “soft.” These modifications affect the nonlinearity and hysteresis, whose control is essential in many high-precision and high-power devices. However, the origins of the hardening and softening, and the mechanisms through which they contribute to the hysteresis and nonlinearity, are presently not well understood.

In the present work we study the possible effects of defects ordering on the mechanisms that lead to the nonlinearity and hysteresis of the dielectric response. The dielectric properties of hard and soft PZT ceramics at various states of defects ordering are analyzed experimentally in detail. Influence of AC-field cycling, time (aging), and thermal treatment, on hysteresis and nonlinearity were examined. A qualitative model that can account for many experimental observations is presented.