Simulation and ultrasonic study on domain processes in ferroelectrics

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Ferroelectric systems usually contain many different polarization domain states that couple strongly with elastic strain. These domains will co-exist and form complex structures, for example, the 90° twins in a tetragonal ferroelectric system. Theoretically speaking, during the polarization reversal process in a single crystal, domains whose polarization axis is different from that of the applied field could appear. However, textbook mechanism for polarization reversal did not include polarization rotation. It was described as a three-step process: reversed polarization domain nucleation, forward growth, and sideway growth of the reversed polarization state. Optical microscopy cannot see these domain switching processes since the mini-domain mixture will appear uniform to the visible light. In addition, some materials may not even be optically transparent. TEM, on the other hand, will destroy the 3D nature of the ferroelectrics and the boundary constraints often confine the switching process. Recently, we have performed a computer simulation as well as innovative measurements of the domain processes using ultrasonic technique. The simulation results of a 2D four variant model show that the switching path is not as given in the textbook. Instead, two consecutive 90° domain switching occurred. In order to verify this phenomena, we have monitored the polarization reversal process using ultrasound in a single crystal $0.955Pb(Zn_{1/3}Nb_{2/3})O_3$–$0.045PbTiO_3$ which has a rhombohedral 3m symmetry. Direct evidence indicates that the polarization reversal in this system is via a path involves two consecutive domain switching processes, i.e., $0° \rightarrow 71° \rightarrow 180°$, instead of the textbook mechanism of $0° \rightarrow 180°$ domain switching. Our results revealed the intrinsic nature of fatigue in some ferroelectrics in which the reversal process involves large elastic deformation.

doi: 10.1016/j.ceramint.2004.03.011

Piezoelectric microactuator arrays using composite PZT thick films

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Preparing crack-free lead zirconate titanate (PZT) films with thickness up to 50 μm is still a challenge for ferroelectric MEMS applications. In this paper, a modified 0–3 composite route for thick film preparation has been reported. The film properties such as microstructure, crystallinity, ferroelectric, and dielectric properties have been optimized in terms of the variable processing parameters such as concentration of the sol–gel solution, powder/solution mass ratio, vehicle content, annealing temperature, powder size, and cold isostatic pressing. Within the optimum processing conditions, the thickness of crack-free PZT films on the platinum-coated silicon substrates can be easily adjusted between 1 and 50 μm. PZT/silicon diaphragm array with such composite thick films has been fabricated by using silicon micromachining. The electromechanical properties of the diaphragms have also been evaluated and presented.

doi: 10.1016/j.ceramint.2004.03.012

Novel high-pressure crystallization process for the preparation of electronic ceramic thin films at low temperatures

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The research and development of thin-film technology for electronic ceramics has been stimulated by the necessity for producing microelectronic devices and systems having compact size, light weight, and low power consumption. Electronic ceramic thin films are being extensively applied in various types of electronic and optical devices such as microelectromechanical systems, dielectric capacitors, sensors, and electro-optic displays.

Because the electronic ceramic thin films are difficult to be crystallized, either in situ heating or post-annealing high temperatures for complete crystallization is necessary. In order to reduce the crystallization temperature of electronic ceramic thin films, a novel high-pressure crystallization (HPC) process has been developed. The crystallization temperatures of ceramic thin films (PZT and Ta_2O_5) were significantly decreased to lower than 400 °C. It was found that the crystallization process of ceramic thin films was markedly enhanced by high-pressure processing. In addition, the interactions between ceramic films and substrates were substantially reduced. The formation process and development of the microstructure were investigated by XRD, GIXD, SEM, and SIMS. The prepared thin films were demonstrated to exhibit high dielectric constants and good electric properties. This HPC approach for synthesizing electronic ceramic thin films can effectively reduce the thermal budget and alleviate the malfunctions resulting from pronounced interdiffusion