Chemical Solution Deposition and in-situ Structural Characterization of Pb-free, Bi-based, Piezoelectric Thin Films

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Abstract

This work explores the electric field induced strain mechanisms in environmentally benign $Bi_{0.5}Na_{0.5}TiO_3$ (BNT) based piezoelectric thin films. Although BNT-based materials show promise as replacements for toxic Pb-based piezoelectrics, the displacement mechanisms are not consistent between thin films and bulk materials, and the differences have yet to be well understood. Here, in-situ structural characterization (2-dimensional X-Ray Diffraction (XRD^2)) under applied field has been utilized and the effects of substrate clamping have been shown to be a large contributor to the differences between bulk and thin film embodiments.

Piezoelectric materials convert mechanical strain into dielectric displacement, and the converse, making these materials suitable for use as sensors, actuators, and transducers. Lead-based materials have received the most attention due to their high strain response and tunability, but the toxicity of lead is leading to legislative directives limiting its use. This is driving a search for suitable replacement materials, and BNT-based ergodic relaxor materials in bulk embodiments display properties that make them ideal for actuator applications. In thin film embodiments of the same materials, however, the response appears to be quite different.

While 80-20 BNKT is the most researched BNT-based system, there remain differences in displacement response between films and bulk that have not been explained. In the BNT-BKT-*x*BMgT system, the differences between films and bulk are even more pronounced, with bulk systems showing a displacement response almost 8 times that of thin films. The in-situ XRD^2 experiments have revealed that the fully clamped film embodiments undergo an irreversible strain with application of field but not a phase change as seen in bulk. Also, strain is almost entirely due to intrinsic effects and little extrinsic (non-180° domain rotation) effects. In partially released films, however, signs of phase change under applied field are present, and extrinsic effects are more prominent. These results show that the clamping stresses due to the substrate may be causing some of the differences between bulk and thin film embodiments.

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