Thin Films via Chemical Solution Deposition synthesis from the $(Bi_{0.5}Na_{0.5})TiO_3$-$(Bi_{0.5}K_{0.5})TiO_3$-$Bi(Mg_{0.5}Ti_{0.5})O_3$ ternary system

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Abstract

The ternary system $(Bi_{0.5}Na_{0.5})TiO_3$-$(Bi_{0.5}K_{0.5})TiO_3$-$Bi(Mg_{0.5}Ti_{0.5})O_3$ (BNT-BKT-BMgT) was explored along the $[75-(x/2)]Bi_{0.5}Na_{0.5}TiO_3$ - $[25-(x/2)]Bi_{0.5}K_{0.5}TiO_3$ - $[x]Bi(Mg_{0.5}Ti_{0.5})O_3$ composition line. Thin films were fabricated using chelated mixing route solutions spin cast onto platinized silicon substrates. Processing parameters such as: excess cation molar%, solution molality, and crystallization temperatures, for composition where x=0, 5, 10, 20, 30, were optimized. The thin films of ~ 200nm thickness displayed ~15% and ~5% change in piezoelectric properties over the composition range for $d_{33,f}^*$ and S_{max}, respectively. The ferroelectric properties showed a minimum at x=10 for the coercive field and maximum at x=5, 30 for maximum polarization. Additionally, the fatigue characteristics at x=0, 5, 10 were studied using bipolar cycling up to 10^9 cycles. A drop in $d_{33,f}^*$ and S_{max} is seen beginning at 10^7 cycles for all compositions while polarization increased for compositions where x=0, 5, but not for x=10. The coercive field also increased with increasing number of cycles starting at 10^5 and 10^7 for compositions where x=0, 5 and x=10, respectively. The polarization vs electric field hysteresis loops for the fatigued samples show a transformation from saturated slim loops to unsaturated broad loops, indicative of lossy behavior, for compositions where x=0, 5, however, hysteresis loops for the composition where x=10 displayed saturated slim loops for $1 \rightarrow 10^9$ cycles. The piezoelectric properties for x=0, 5, 10 showed a 27%, 28%, and 34% drop in $d_{33,f}^*$ at 10^9 cycles, respectively. Here the optimal processing conditions were found for the compositions with increasing mol% of BMgT. The piezoelectric and ferroelectric properties of resulting thin films were compared for the composition range and films of selected composition were subjected to bipolar field cycling for up to 10^9 cycles. The BNT-BKT-BMgT derived thin films demonstrated piezoelectric characteristics desirable for actuators, such as minimal negative strain and maximum strains comparable to bulk ceramic embodiments. The composition study revealed differences in the observed piezoelectric properties vs. composition for thin films vs. bulk ceramics, mainly the lack of a maximum in $d_{33,f}^*$ as a function of composition for the thin films as it is observed for bulk ceramics. Fatigue resistance for selected compositions demonstrated improvement over other bismuth sodium titanate binary and ternary systems and were comparable to doped lead compounds for up to 10^9 cycles.

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