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Relaxor Ferroelectric Lead-Free $Na_{0.52}K_{0.44}Li_{0.04}Nb_{0.84}Ta_{0.10}Sb_{0.06}O_3$ Ceramic: Giant Electromechanical Response with Intrinsic Polarization and Resistive Leakage Analyses

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Abstract : Environment-friendly lead-free $Na_{0.52}K_{0.44}Li_{0.04}Nb_{0.84}Ta_{0.10}Sb_{0.06}O_3$ (NKLNTS) ceramic was synthesized by solid-state reaction method in search of a potential candidate to replace lead-based ceramics such as $PbZrO_3$-$PbTiO_3$ (PZT), $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) etc., for various applications. The ceramic was calcined at temperature 850 °C and sintered at 1090 °C. The powder X-Ray Diffraction (XRD) pattern revealed the formation of pure perovskite phase having tetragonal symmetry with space group P4mm of the synthesized ceramic. The surface morphology of the ceramic was studied using Field Emission Scanning Electron Microscopy (FESEM) technique. The well-defined grains with homogeneous microstructure were observed. The average grain size was found to be ~ 0.6 µm. A very large value of piezoelectric charge coefficient (d_{33} ~ 754 pm/V) was obtained for the synthesized ceramic which indicated its potential for use in transducers and actuators. In dielectric measurements, a high value of ferroelectric to paraelectric phase transition temperature (Tm~305 °C), a high value of maximum dielectric permittivity ~ 2110 (at 1 kHz) and a very small value of dielectric loss (< 0.6) were obtained which suggested the utility of NKLNTS ceramic in high-temperature ferroelectric devices. Also, the degree of diffuseness (γ) was found to be 1.61 which confirmed a relaxor ferroelectric behavior in NKLNTS ceramic. P-E hysteresis loop was traced and the value of spontaneous polarization was found to be ~11µC/cm² at room temperature. The pyroelectric coefficient was obtained to be very high (p ~ 1870 $\mu Cm^{-2}\,{}^{o}C^{-1}$) for the present case indicating its applicability in pyroelectric detector applications including fire and burglar alarms, infrared imaging, etc. NKLNTS ceramic showed fatigue free behavior over 107 switching cycles. Remanent hysteresis task was performed to determine the true-remanent (or intrinsic) polarization of NKLNTS ceramic by eliminating non-switchable components which showed that a major portion (83.10 %) of the remanent polarization (Pr) is switchable in the sample which makes NKLNTS ceramic a suitable material for memory switching devices applications. Time-Dependent Compensated (TDC) hysteresis task was carried out which revealed resistive leakage free nature of the ceramic. The performance of NKLNTS ceramic was found to be superior to many lead based piezoceramics and hence can effectively replace them for use in piezoelectric, pyroelectric and long duration ferroelectric applications.

Keywords : dielectric properties, ferroelectric properties , lead free ceramic, piezoelectric property, solid state reaction, true-remanent polarization
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