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Effect of High-Energy Ball Milling on the Electrical and Piezoelectric Properties of (K0.5Na0.5)(Nb0.9Ta0.1)O3 Lead-Free Piezoceramics

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Abstract : Nanocrystalline powders of the lead-free piezoelectric material, tantalum-substituted potassium sodium niobate (K0.5Na0.5)(Nb0.9Ta0.1)O3 (KNNT), were produced using a Retsch PM100 planetary ball mill by setting the milling time to 15h, 20h, 25h, 30h, 35h and 40h, at a fixed speed of 250rpm. The average particle size of the milled powders was found to decrease from 12nm to 3nm as the milling time increases from 15h to 25h, which is in agreement with the existing theoretical model. An anomalous increase to 98nm and then a drop to 3nm in the particle size were observed as the milling time further increases to 30h and 40h respectively. Various sizes of these starting KNNT powders were used to investigate the effect of milling time on the microstructure, dielectric properties, phase transitions and piezoelectric properties of the resulting KNNT ceramics. The particle size of starting KNNT was somewhat proportional to the grain size. As the milling time increases from 15h to 25h, the resulting ceramics exhibit enhancement in the values of relative density from 94.8% to 95.8%, room temperature dielectric constant (εRT) from 878 to 1213, and piezoelectric charge coefficient (d33) from 108pC/N to 128pC/N. For this range of ceramic samples, grain size refinement suppresses the maximum dielectric constant (εmax), shifts the Curie temperature (Tc) to a lower temperature and the orthorhombic-tetragonal phase transition (Tot) to a higher temperature. Further increase of milling time from 25h to 40h produces a gradual degradation in the values of relative density, εRT, and d33 of the resulting ceramics.

Keywords : perovskite, dielectric, ceramics, high-energy milling
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