Antiferroelectric Ceramics for High Energy Density Capacitors and Large Strain Actuators

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Antiferroelectric (AFE) materials display a characteristic electric field induced phase transition from an antiferroelectric to a ferroelectric (FE) phase. This transition is accompanied by a large field induced strain, which lends the antiferroelectrics an edge over alternatives for digital actuator applications. Additionally, the double hysteresis loop that is characteristically observed in the electric field induced polarization response of the antiferroelectrics provides a possibility to built high-energy storage capacitors.

Lead zirconate - PZ ($PbZrO_3$) rich compositions in the lead zirconate titanate – PZT solid solutions are well known antiferroelectric materials. However, they require rather high switching fields and, in bulk ceramic form, they are prone to dielectric breakdown before they can be switched to a FE phase. Modification of the PZT system with tin $Pb[(Zr_{1-x}Sn_x)_{1-y}Ti_y]O_3$ (PZST) or with lanthanum $(Pb_{1-x}La_x)(Zr_{1-y}Ti_y)O_3$ (PLZT) reduces the required E-fields to levels that are attainable in bulk ceramic form. There are also examples of lead-free antiferroelectrics such as $NaNbO_3$ (NN) or rare-earth doped $Bi_{0.5}Na_{0.5}TiO_3$– $Bi_{0.5}K_{0.5}TiO_3$– $BaTiO_3$ (BNT–BKT–BT) ceramics.

This study reviews the high energy density capacitor and high strain actuator applications of antiferroelectrics. Results of our studies on the effects of:

(i) Compositional variation and Nb-doping on PZST,
(ii) La content on the $(Pb_{1-x}La_x)(Zr_{0.70}Ti_{0.30})O_3$, and
(iii) Rare-earth doping on the lead-free (0.854BNT–0.12BKT–0.026BT) ceramics were discussed in detail.

Net energy density values > 1 J/cm^3 and field induced strain levels > 0.4% have been observed in the aforementioned systems. The results were discussed and explained based on the defect chemistry created as a result of doping and stability of the phases in these systems.