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Status of polycrystalline relaxor-PT piezoelectric ceramics

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Perovskites like Pb (A B) O_3, called relaxor materials, are electrostrictive in nature with cubic-rhombohedra structure whereas $PbZrO_3$ and $PbTiO_3$ are ferroelectric having rhombohedra and tetragonal structures respectively. Relaxor materials show a strong dielectric relaxation behavior, why they are called relaxor. Its dielectric constant dependence on temperature shows a broad peak which shifts towards higher temperature at higher frequencies. Ferroelectric materials show a critical temperature, Curie temperature, at which the dielectric constant peaks. Compositions based on relaxor material with ferroelectric $PbTiO_3$ form morphotropic phase boundary (MPB) at which rhombohedra to tetragonal phases coexist which makes the material easily polarizable with piezoelectric properties. It is similar to the MPB formed in piezoelectric ceramic materials, lead zirconatetitanate ($PbZrTiO_3$), but is inherently weaker as relaxor materials have partially orthorhombic with rhombohedra structure.

$Pb(Mg_xNb_{1-x})O_3$-$PbTiO_3$ (PMN-PT)relaxor-ferroelectric ceramics have shown piezoelectric properties which are not as promising as Pb (ZrTi) O_3. However, PMN-PT form single crystals which have shown ultra-high longitudinal piezoelectric strain coefficient d_{33} (>2000 pC/N) and electromechanical coupling factor k_{33} (>0.9), much more than that shown by conventional piezoelectric ceramics. These merits have made these promising for a broad range of applications as ultrasonic transducers and piezoelectric actuators. Pb $(Mg_{1/3}Nb_{2/3})$ O_3-$PbTiO_3$ (PMN-PT) and Pb $(Zn_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PZN-PT) However, relaxor-PT binary systems have the drawbacks of low Curie temperature and low coercive fields. Second generation ternary systems like PMN-PZT-PT and PMN-PIN-PT have subsequently been investigated in recent years with much improved characteristics. Some of the single crystal relaxor-piezoelectrics based on binary and ternary systems have been commercialized. Piezoelectric ceramic ternary systems PMN-PIN-PT, PZN-PIN-PT have however higher Curie temperature and thus superior temperature stability, have higher coercive fields and hence low depolarization and superior ageing characteristics. Ceramic ternary systems have shown dielectric and piezoelectric properties comparable to PZTs. The effect of doping and changing the grain size on electro-mechanical and dielectric properties, which are known as intrinsic and extrinsic effects have not been sufficiently investigated in these systems. Both of these parameters affect the movement of ferroelectric domains and hence the dielectric and piezoelectric properties of these piezo-ceramics. Studies indicate that the optimum ratio of PMN and PT is different for relaxor-PT ceramics at PMN-36%PT in comparison to the ratio PMN-33%PT for single crystals as can be seen from the Table below [1, 2].

Table 1: Comparison of properties of PMN-36%PT and PMN-33%PT

	E_{33}^T	d_{33} (pC/N)	Q_m	T_c°C	E_c (V/mm)
PMN-33%PT	2920	453	124	160	180
PMN-36%PT	4830	499	17	580	710

Likewise, other workers [3, 4]have shown the effect of grain size and doping on properties of PZT piezo-ceramics on the dielectric and piezoelectric properties. This paper presents a review study on the effect of grain size and doping on the dielectric and piezoelectric properties of ternary relaxor-PT ceramics. A study of likely effect on the properties of ternary relaxor-PT systems has been done with a view to suggest future perspective on improving the characteristics of these materials.

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