High Performance Piezoelectric Ceramics and Crystals

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Background, Motivation and Objective

Piezoelectric materials lie at the heart of electromechanical transducers. Applications include actuators, underwater sonar, non-destructive evaluation (NDE) resonators, sensors and medical ultrasound. The piezoelectric coefficient d_{33}, electromechanical coupling (k_{33}) and dielectric permittivity ($\varepsilon_{33}/\varepsilon_0$) are key parameters in determining device performance. In this paper, we review current "state of the art" polycrystalline and single crystal piezoelectric materials, that include modified PZT ceramics and Relaxor-PT based ferroelectric crystals, the later offering ultrahigh electromechanical coupling coefficients k_{33}s >90% vs 75% for ceramics.

Though limited in coupling, advances continue to be made in polycrystalline piezoelectrics including reduced grain size, allowing finer scale machining and increasing coercive field and thus, field stability during device operation. Fabrication of 5 inch diameter Relaxor PT crystals (PMN PT) and 4 inch PIN-PMN-PT crystals offer significant cost reduction, opening up new market areas.

Results/Discussion

Recent developments have experimentally confirmed that the piezoelectricity of relaxor ferroelectric can be further improved by introducing local structural heterogeneity via a dopant strategy. Both modified polycrystalline ceramics and single crystals were found to exhibit ultrahigh piezoelectric coefficients d_{33}, (ceramics up to 1500pC/N and single crystals up to 4000pC/N). Furthermore, the dielectric permittivity was found to be greater than 10,000 with a relatively good temperature stability compared to state of the art "soft" piezoelectrics, see figure 1 [1]. Investigations on the role of AC poling to further enhance properties will also be presented.

Ceramics	$\varepsilon_{33}/\varepsilon_0$	d_{33} (pC N^{-1})
PMN-29PT	2600	360
PMN-36PT	5200	620
* 2.5Sm-PMN-29PT	13000	1510
* 2.5Sm-PMN-31PT	10000	1250
Commercial PZT5H	3400	650
Commercial PZT5	1700	500

Note: d_{33} measured by Berlincourt d_{33}-meter

* This work

Figure Piezoelectric and dielectric properties of Sm-PMN-PT ceramics. Comparison of piezoelectric coefficients and relative dielectric permittivities of the 2.5Sm-PMN-29PT and 2.5Sm-PMN-31PT ceramics with PMN-*x*PT and state-of-the-art "soft" PZT ceramics.

[1] F. Li, D. Lin, Z. Chen, Z. Cheng, J. Wang, Z. Xu, Q. Huang, X. Liao, L. Q. Chen, T. R. Shrout and S. J. Zhang, "Ultrahigh piezoelectricity in ferroelectric ceramics by design," Nature Materials 17 (2018) 349-354.