# Development and Understanding of High-Performance Piezo-/ferroelectric Single Crystals."

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Relaxor-based single crystals of complex perovskite solid solutions, $Pb(Mg_{1/3}Nb_{2/3})O_3$–$PbTiO_3$ [PMN–PT] and $Pb(Zn_{1/3}Nb_{2/3})O_3$–$PbTiO_3$ [PZN–PT], exhibit extraordinary piezoelectric performance – with extremely high piezoelectric coefficients ($d_{33}$ > 2500 pC/N), very large electromechanical couple factors ($k_{33}$ > 90%) and exceptionally high strain levels (> 1%) – that outperforms the widely used $Pb(Zr_{1-x}Ti_x)O_3$ (PZT) ceramics, making them the materials of choice for the next generation of electromechanical transducers for a broad range of advanced applications. To further improve the binary materials' properties, new piezocrystals of ternary relaxor-PT solid solutions (Generation II, represented by $Pb(In_{1/2}Nb_{1/2})O_3$–$Pb(Mg_{1/3}Nb_{2/3})O_3$–$PbTiO_3$ [PIN–PMN–PT]) and doped relaxor–PT solid solutions (Generation III) have recently been developed.

In this tutorial, we present an overview on the recent developments in high-performance piezo-/ferroelectric crystals, and the current understanding of their fundamental structure – property relations. A wide spectrum of topics will be covered in three parts. Part I will focus on the development of PMN-PT and PZN-PT piezocrystals and their applications, including crystal chemistry and materials design, phase diagrams, solid solutions, crystal growth techniques and principles, and various devices. Part II will review the macroscopic properties of relaxor-based piezocrystals and the present understanding of the molecular mechanisms of their outstanding properties in terms of crystal structure and phase symmetry, morphotropic phase boundary (MPB) and its effects, phase transitions, dielectric relaxation, piezoelectric and ferroelectric properties, domain structures from mesoscopic to nanoscopic scale, and electric field-induced effects. Part III will present the recent developments of new materials systems beyond PMN-PT and PZN-PT, including the ternary piezocrystals, the high-temperature piezoelectrics, and the PZT single crystals, and discuss the challenges and perspectives in this fascinating field.

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