Phenomenology of Transducer Materials

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This talk will review the application of the phenomenological theory to transducer materials based on binary and ternary solid solutions comprising barium titanate, lead titanate and/or relaxor ferroelectrics as end member compounds. A particular form of the Ginzburg-Landau theory is adopted that places special emphasis on the role played by the crystallographic anisotropy of polarization at inter-ferroelectric transitions. Relations are developed that specify the stability of the proper symmetry ferroelectric phases in terms of the coefficients of the Landau series. Analytical expressions are derived that describe key topological features of binary and ternary phase diagrams, dielectric and piezoelectric property maps are computed, and relationships existing between crystallographic anisotropy of polarization and extrema in electromechanical properties are illustrated. The computations demonstrate that topologically distinct phase diagram types share a common feature: a line in the composition-temperature plane along which the crystallographic anisotropy of polarization is dramatically reduced. This observation provides insights into experimental observations of tricritical behavior, nanodomain structure, low-symmetry ferroelectric phases, and extrinsic contributions to electromechanical properties. However, if diffusional processes are operative, the equilibrium boundary lines of the diffusionless phase diagrams are replaced by two-phase fields. Taking into account the free energy of mixing, possible topologies of the corresponding equilibrium phase diagrams are computed, with implications for processing-property relations in these materials. The inherent simplicity of the theory, together with the unified analytical parameterization scheme employed, is expected to be useful for guiding experimental investigations of ferroelectric solid solutions, in generating free energy functions for phase field simulations, and for developing first-principles-derived thermodynamic descriptions for ferroelectric materials. Where appropriate, comparisons of predicted and observed behaviors will be highlighted.