The Line of Critical Points and the Giant Electromechanical Response in a Ferroelectric Relaxor System

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The direct conversion of electrical energy to mechanical work by a material response is of great importance for a number of applications from robotics to development of artificial muscles. The giant electromechanical response in ferroelectric relaxors such as $Pb(Mg_{1/3}Nb_{2/3})O_3$ – $PbTiO_3$ (PMN-PT) is opening new horizons in ultrasonic and medical applications, as well as in telecommunications. The origin of this effect, however, is still the subject of intensive research. Here we show that the giant electromechanical effect can be attributed to the existence of a line of critical points in these systems. In the electric field (E) – temperature (T) – PT concentration (x) phase diagram of PMN-PT, the first order paraelectric – ferroelectric phase transitions end in a line of critical points above which supercritical evolution has been observed by means of high resolution calorimetry and dielectric spectroscopy. Three new phase transitions, previously not reported, were also found in the T-x-E phase diagram of PMN-PT near the cubic-tetragonal-rhombohedral triple point. The enthalpy, static dielectric constant, and piezoelectric coefficient exhibit maximum values at the critical point values of E and T for a particular x. The flatness of the free energy surface near the critical point allows for large fluctuations and polarization rotation even in small electric fields, thus explaining the giant electromechanical response of relaxors.