Phase transition in uniform, poled bulk ferroelectrics

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What is phase transition?

Phase transitions occur when the <u>thermodynamic</u> <u>free energy</u> of a system is <u>non-analytic</u> for some choice of thermodynamic variables (T, σ , P, M etc.)

$$dF = -PdV - SdT + \mu dn + MdH + PdE$$



PVT diagram for water

How to understand phase transition?

Phenomenology	Ferroelectric (near Tc)
Laudau-Devonshire Theroy (Uniform Polarization)	Poled Bulk System
Laudau-Ginzburg Theory (Polarization with Spatial Gradient)	Bulk System
Laudau-Ginzburg Theory with Boundary Conditions	Film

Landau-Devonshire theory

$$F_P = \frac{1}{2}aP^2 + \frac{1}{4}bP^4 + \frac{1}{6}cP^6 - EP$$

similar to phonon mode, plus rotational covariance.

Equilibrium condition: $\frac{\partial F_P}{\partial P} = 0$

$$E = aP + bP^3 + cP^5$$

$$\chi = \frac{P}{E} = \frac{1}{a} = \frac{1}{a_0(T - T_0)},$$

 \rightarrow

with
$$P = \chi(E + \lambda P)$$

b>0



b<0



P-E loop

