Field-Induced Switching of Ferro-Quadrupole Order Parameter in $PrTi_2Al_{20}$

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The cubic compound $PrTi_2Al_{20}$ has the non-magnetic ground states of crystal field (Γ_3). The Γ_3 doublet have two pure electric quadrupoles of the Γ_3-type, O_{20} ($3z^2$-r^2) and O_{22} (x^2-y^2), and magnetic octupole of Γ_2-type, T_{xyz}=xyz [1, 2]. The various measurements, such as specific heat, ultrasonic, neutron and NMR, reported that the ferro-quadrupole transition occurs near 2 K in this compound [3-6].

In this presentation, we will discuss the H - T phase diagrams from ^{27}Al-NMR and magnetization measurements in a single crystal of $PrTi_2Al_{20}$. When a magnetic field is applied along the [111] direction above 0.5 T, certain lines of the NMR spectrum split upon entering into the ordered phase, indicating breaking of the C_3 symmetry due to field induced magnetic dipole moment perpendicular to the field. This provides the first evidence for symmetry-breaking ferro-quadrupole order of O_{20} type[6].

Recently, we observed the clear anomaly for the field-induced transition (the first transition) associated with the quadrupole moments near 2 T and 1.5 T for H || [001] and [110] from NMR spectra and magnetization [7]. However, for H || [111], the absence of an anomaly occurs between 0.5 T and 11 T, suggesting the phase diagram has single ordered phase[6, 7]. The origin of anisotropic field induced transition is the competition between Zeeman interaction and ferro-quadrupole interaction coupled with the magnetic field. We will then present the detail of these experimental results and our calculation of Free energy for this system with mean field theory.

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