Magnetic structure analysis of Mutiferroic material of $EuMn_2O_5$

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$EuMn_2O_5$ is one of the prototypical multiferroics of RMn_2O_5 (R = Y, Bi, rare-earth, in which antiferromagnetism and ferroelectricity coexists and their order parameters are mutually coupled. Because of the huge neutron absorption cross section of Eu, microscopic magnetism and its relation to the ferroelectricity have not been revealed so far. Thus we have grown the single crystal of $^{153}EuMn_2O_5$ and carried out neutron diffraction experiments. The experiments were performed at Four-Circle-Diffractometer FCD installed in HANARO reactor of KAERI and FONDER installed in JRR-3M of JAEA.

As shown in Fig. 1, antiferromagnetic order appears below T = 40 K, where the electric polarization along the b-axis arises concomitantly. A magnetic propagation wave vector $\mathbf{q}_M$ of this material is (1/2, 0, q_z) with $q_z \sim 1/3$. Quite interestingly around T = 22 K, the electric polarization suddenly drops and almost disappears, indicating the phase transition from ferroelectric to antiferroelectric or paraelectric phase. At the phase transition $\mathbf{q}_M$ does not change at all. However as shown in Fig. 1 (b) and (c), the temperature dependence of magnetic Bragg intensity around Q = (0.5, 0, 1.66) is different from that around Q = (1.5, 0, 0.33), where the intensity around Q = (1.5, 0, 0.33) steeply increases below $T \sim 22$ K. This indicates that the magnetic structure changes at this temperature without changing $\mathbf{q}_M$.

We also performed magnetic structure analysis at T = 25 K and at T = 15 K. At 25 K in the ferroelectric phase, cycloidal magnetic structure in the bc -plane as well as in the ac-plane is realized as another RMn_2O_5 system also realizes. In the bc-plane, the relation of spin chirality ($\equiv \mathbf{S}_i \times \mathbf{S}_j$) between neighbored cycloidal magnetic chains is in-phase, which can induce the electric polarization along the b-axis as a result of an inverse effect of Dzyaloshinski-Moriya (DM) interaction. At T = 15 K in anti- or paraelectric phase, the cycloidal magnetic structure in the bc -plane and in the ac-plane is maintained. However, the relation of spin chiralitybetween neighbored cycloidal magnetic chains becomes anti-phase, suggesting that the local polarization induced by the each cycloidal chain compensates with each other.

The results suggest that the disappearance of the electric polarization can be explained by the spontaneous flip of the chirality of the cycloidal spin chain in the bc-plane.

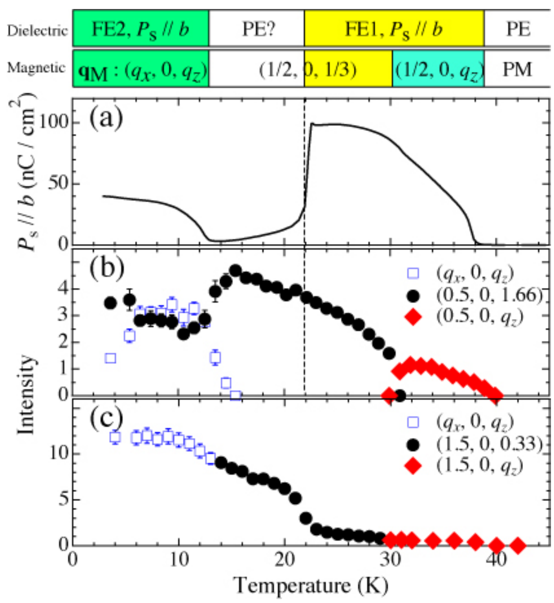

Fig. 1. Temperature dependence of (a) electric polarization along the b-axis, (b) magnetic Bragg reflection around $Q \sim$ (0.5, 0, 1.75), and (c) around $Q \sim$ (1.5, 0, 0.33). Dielectric and magnetic phase diagram is shown in the top of the figure.