Mechanism of Magneto-electric effect of $Tb_{0.5}Gd_{0.5}Mn_2O_5$

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Multiferroics, which exhibit ferroelectricity driven by magnetic ordering, have been subjected to intensive investigation for several decades. Among these materials, RMn$_2$O$_5$ (R = rare-earth) family has attracted much attention due to their various and complex magnetoelectric (ME) effect, where striking change in dielectric (magnetic) properties results from magnetic (electric) field, depending on the type of rare-earth ion. In our prior study [1], we investigated $Tb_{0.5}Gd_{0.5}Mn_2O_5$ to explore new type of ME effect. We discovered a novel dielectric phase below T_c = 14 K, in which the electric polarization abruptly vanishes [as shown in Fig.1 (a)]. In addition, the electric polarization re-emerges under external magnetic field. Notably, this ME effect occurs in response to the application of magnetic field along each crystallographic axis. This isotropic ME effect is distinct from those observed in other RMn$_2$O$_5$ and multiferroic compounds. In order to elucidate the underlying causes of the disappearance of the electric polarization below T_c and the novel ME effect, we performed neutron scattering experiments on this material.

Neutron scattering experiments have been done at Fonder installed in JRR3 for single crystals of $Tb_{0.5}Gd_{0.5}Mn_2O_5$. We collected many magnetic Bragg diffraction intensities at each temperature to do magnetic structure analyses. Typical results of our analyses are shown in Figs. 1 (b) and (c), which display the magnetic structure of Mn ions at T = 2.5 K and T = 16 K. The cycloidal magnetic structure along the c-axis detected at T = 16 K, indicating that the electric polarization of this material is induced by this cycloidal magnetic structure via Spin-Current model [2]. In contrast, this cycloidal magnetic structure changes to sinusoidal-like one below T = 14 K. According to this results, the vanishment of the electric polarization at T = 14 K can be attributed to the disappearance of the cycloidal magnetic structure of Mn ions.

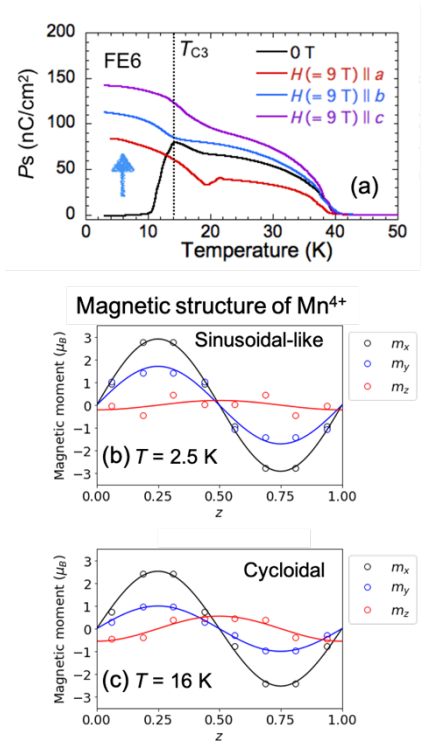

Fig.1 (a) Temperature dependence of electric polarization of $Tb_{0.5}Gd_{0.5}Mn_2O_5$. (b)(c)Magnetic structure of Mn ion at T = 2.5 K and 16 K, obtained by the present neutron scattering experiments.

[1] Y. Ishii, et al., PRB., 100, 104416 (2019).

[2] H. Katsura, et al., PRL. 95, 057205 (2005).