

Electric Control of Magnetic Anisotropy in Multiferroics $\text{Ba}_2\text{CoGe}_2\text{O}_7$

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The multiferroic system $\text{Ba}_2\text{CoGe}_2\text{O}_7$ has the unique anisotropy of the magnetic moments originated from the magnetoelectric effect. Our polarized neutron scattering results with the electrical field indicates that the rotation angle of the magnetic moments increases gradually with increasing the electrical field.

Recently, novel relationships between magnetism and electricity, *multiferroics*, are attracting great interest of researchers in the fields of materials science and condensed matter physics. In the typical multiferroic system, the ferroelectricity is induced by a cycloidal magnetic ordering and a proper-screw magnetic ordering. The magnetization appears in response to an electric field, and the application of a magnetic field H causes a change in electric polarization P . These couplings of the magnetic and polarization orders are known as dc magnetoelectric (ME) effects. In the low energy excitations, on the other hand, the oscillating magnetization and polarization can be also induced by the electric and magnetic component of light, respectively. The hybridization of the spin and the polarization waves is known as electromagnon, as discussed in TbMnO_3 and TbMn_2O_5 . Recently, new type of multiferroics and electromagnon of which the origin is d - p hybridization mechanism are reported in tetragonal $\text{Ba}_2\text{CoGe}_2\text{O}_7$ [1,2].

$\text{Ba}_2\text{CoGe}_2\text{O}_7$ having the noncentrosymmetric crystal structure shows a staggered antiferromagnetic structure in the (001) plane below $T_N=6.7$ K. Below T_N , a ferroelectric polarization is observed under H . In $\text{Ba}_2\text{CoGe}_2\text{O}_7$, Murakawa and co-workers have shown that the ferroelectricity is induced by the spin-dependent d - p hybridization mechanism. Previously, we have performed inelastic neutron scattering to identify the electromagnon observed by light scattering experiment. All the excitations in zero field are reasonably reproduced by the extended spin wave theory without considering magnetoelectric effects. On the other hand, we have also clarified that the anisotropy of the magnetic moments connects with the multiferroic property of $\text{Ba}_2\text{CoGe}_2\text{O}_7$. Figure 1(a) and 1(b) show the directions of the electrical polarization of each CoO_4 tetrahedron for the $S//\langle 100 \rangle$ and $S//\langle 110 \rangle$, respectively. The ferroelectricity is realized in the $S//\langle 110 \rangle$, while the $S//\langle 100 \rangle$ induces the antiferroelectricity. In the previous inelastic neutron study, we have found the existence of ~ 0.1 meV anisotropy gap between (a) and (b) states.

In order to clarify the unique magnetic anisotropy with the multiferroic property, we have carried out the polarized neutron scattering study (TASP) with the electrical field. In the zero field experiment, we have found that the system has the ground state which has the $S//\langle 100 \rangle$ and $S//\langle 010 \rangle$ domains. By applying the electric field along $\pm c$ -axis, on the other hand, the direction of the magnetic moment would be rotated. The results of the polarized neutron experiment indicate that the rotation angle of the magnetic moments increases gradually with increasing the electrical field. This is the first result of electrical control of the magnetic

anisotropy.

References

- [1] H. Murakawa et al., PRL 105 137202 (2010).
- [2] I. Kezsmarki et al., PRL 106 057403 (2011).

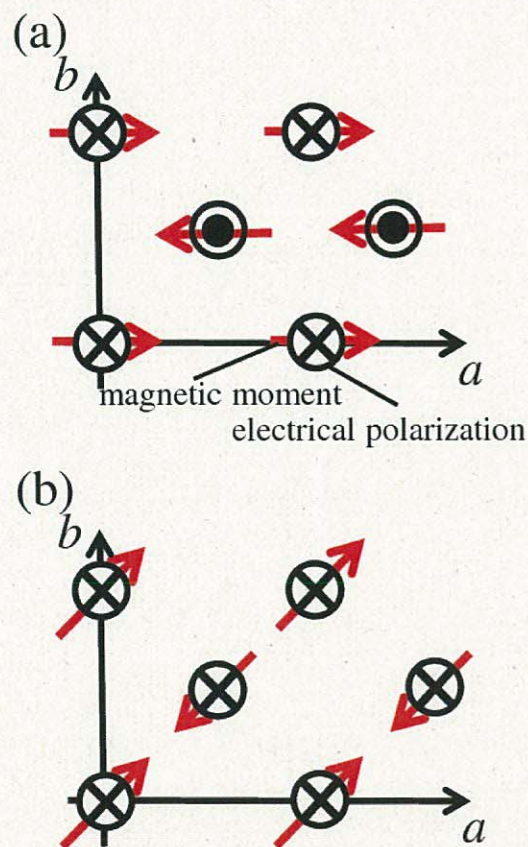


Figure 1: Directions of the electrical polarization of each CoO_4 tetrahedron along c -axis for (a) $S//\langle 100 \rangle$ and (b) $S//\langle 110 \rangle$.

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