MAGNETOELASTIC AND MAGNETOELECTRIC EFFECTS IN A TRIANGULAR LATTICE ANTIFERROMAGNET $CuFeO_2$

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We have investigated the magnetic, magnetoelectric, and magnetoelastic properties of a triangular lattice antiferromagnet $CuFeO_2$ (T_N=14 K) showing magnetic-field-induced collinear-noncollinear magnetic phase transitions [1]. Using a 14-tesla PPMS at NHMFL-LANL, we measured the magnetic field (H) effect of the magnetization, magnetostriction, and magnetoelectric effect in single crystals of $CuFeO_2$ [2].

To illustrate magnetoelastic coupling in $CuFeO_2$, we display in Figs. (a)-(c) magnetization and magnetostriction parallel and perpendicular to the c axis as a function of magnetic fields (//c) at 2 K. Two magnetization steps are evident, as seen in Fig. (a). Only in the field range between the first and second magnetization steps (~6.7 T < H <~13.3 T), the system exhibits a "noncollinear" helimagnetic structure. The multistep magnetic phase transitions are ascribed to nearly degenerate spin states around the ground state due to geometrical frustration in this system.

The magnetostriction also shows two steps, as shown in Figs. (b) and (c). The onset fields of the two steps in the magnetostriction coincide with those of the metamagnetic transition into the noncollinear-helimagnetic and the collinear commensurate (1/5) phases.

Figure (d) shows the magnetic field dependence of electric polarization at 2 K. A comparison of the magnetic field profiles of magnetization with that of electric polarization reveals a strong interplay of the evolution of magnetic structure and electric polarization. The data located in the lower H region of Fig. (d) clearly show that the electric polarization is not induced by H at the collinear-commensurate(1/4) phase. However, the electric polarization exhibits a sudden increase at the transition field into the noncollinear-helimagnetic phase, and becomes finite. With further increasing H, the electric polarization vanishes again at the transition field into the collinear-commensurate(1/5) phase. It should be emphasized that the electric polarization becomes finite only at the noncollinear-helimagnetic phase but not at the collinear-commensurate phases.

In summary, $CuFeO_2$ exhibits magnetic-field-induced collinear-noncollinear magnetic phase transitions, and it is found that finite electric polarization, namely inversion symmetry breaking, occurs with noncollinear but not at collinear magnetic phases. This result provides strong evidence that the noncollinear helical magnetic structure plays a key role in inducing a finite electric polarization for $CuFeO_2$, and suggests that frustrated magnets which often favor noncollinear configurations can be plausible candidates for magnetoelectrics with strong magnetoelectric interaction.

References

[1] Mitsuda, S. *et al*., J. Phys. Soc. Jpn. 69, 3513 (2000).
[2] Kimura, T., Lashley, J. C. and Ramirez, A. P., Phys. Rev. B 73, 220401(R) (2006).

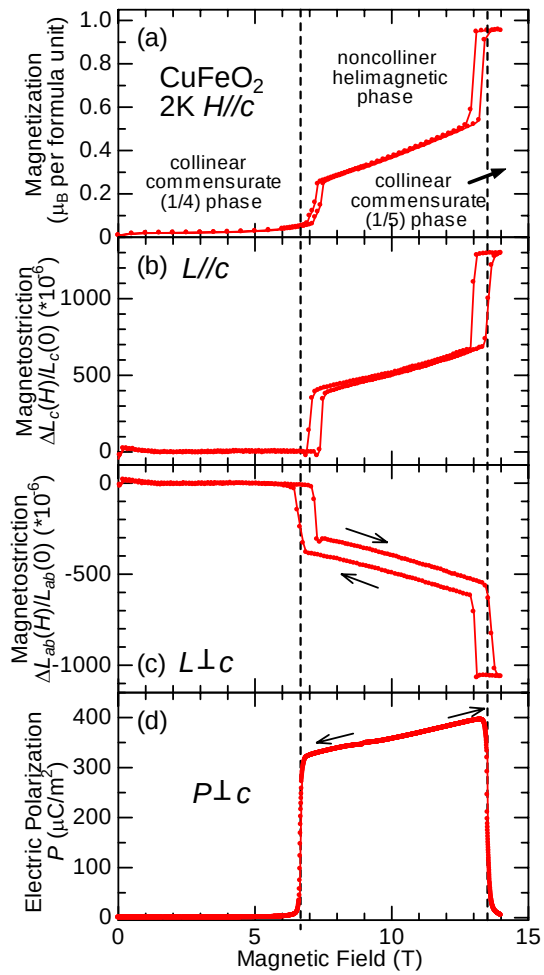

Figure: Magnetization (a), magnetostriction parallel (b) and perpendicular (c) to the c axis, and electric polarization perpendicular to the c axis (d) of $CuFeO_2$ as a function of magnetic field at 2 K. Magnetic field was applied along the c axis.