Uniaxial-pressure control of ferroelectricity in a spin-driven magneto-electric multiferroic CuFe1-xAlxO2

Setsuo Mitsuda, Hiromu Tamatsukuri, Tenhu Nakamura
Department Physics, Faculty of Science, Tokyo University of Science

A triangular lattice antiferromagnet $CuFeO_2$ exhibits a spin driven ferroelectric phase (FE-ICM phase), in which a noncollinear helical magnetic structure breaks inversion symmetry in this system, by substituting a few percent of nonmagnetic Ga^{3+} for magnetic Fe^{3+}. In addition, $CuFeO_2$ is also a strong spin-lattice coupled system, whose magnetic phase transitions are accompanied by crystal lattice distortions owing to the geometrical spin frustration. Therefore, this compound is one of the model materials for investigating novel magneto-electric cross-correlated phenomena induced by anisotropic uniaxial pressure p.

Recently, we found that the application of p along the $[1\bar{1}0]$ direction, which is conjugate to the spontaneous lattice distortion, induces another ferroelectric (FE) phase in $CuFe_{1-x}Ga_xO_2$(x=0.035) (CFGO). Also, temperature dependence of magnetic susceptibility suggests that this ferroelectric transition is accompanied by magnetic phase transition. In order to clarify this point and to investigate a magnetic structure of the p-induced FE phase, we have performed neutron diffraction experiments under applied p, using single crystals of CFGO prepared by the floating zone technique.

The neutron-diffraction measurements under applied p were carried out at the two-axis diffractometer E4 installed at the Berlin Neutron Scattering Center in the Helmholtz Centre Berlin for Materials and Energy. The wavelength of incident neutron was 2.44 Å. Since the direction of p is parallel to the $[1\bar{1}0]$ direction, the scattering plane is the (HHL) plane in the diffraction measurements.

As shown in Fig. 1(a), under applied p of 400 MPa, magnetic modulation wave number q starts to vary at 16 K, which indicates a magnetic phase transition from the well-studied OPD phase. Since electric polarization emerges and dielectric constant shows peak at 16 K, as shown in Fig. 1(b) and (c), this magnetic transition completely corresponds to the p-induced FE transition. On the other hand, the (1/2-q,1/2-q,3/2) magnetic Bragg reflections shown in Fig. 1(a), which are typical indicator of the well-studied noncollinear helical magnetic structure in the FE-ICM phase, could be measured below 9 K even under applied p = 400 MPa. This result indicates that the FE-ICM phase does not be realized at 16 K. Moreover, tentative magnetic structure analysis shows that the magnetic structure in the p-induced FE phase is a collinear one.

In conclusion, we have found that the p-induced FE phase transition is accompanied by magnetic phase transition, and the magnetic structure in this phase is entirely different from the noncollinear helical type in the FE-ICM phase.

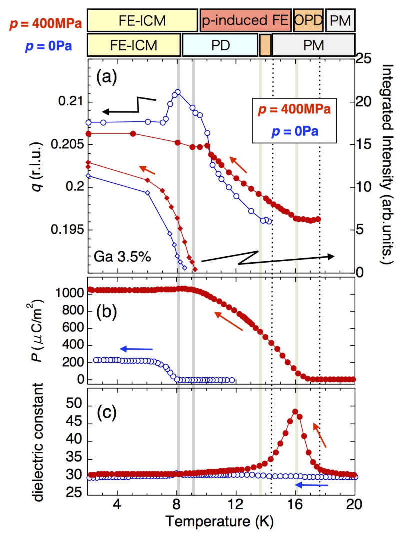

Fig. 1. T dependence on cooling process of (a) q and integrated intensity, (b) electric polarization and (c) dielectric constant.