# Electric polarization memory effect in multiferroic $CuFe_{1-x}Ga_xO_2$: Polarized neutron diffraction study

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Multiferroic $CuFe_{1-x}Ga_xO_2$ (CFGO) with $x = 0.035$ exhibits spin-driven ferroelectricity in a screw-type helimagnetic phase below 8 K. In previous study, we have revealed that the ferroelectric polarization ($P$) emerges along the screw axis of the magnetic structure, and the polarity of $P$ is determined by the spin-helicity, i.e., the left-handed (LH) or right-handed (RH) helical arrangement of the spins[1]. In the ferroelectric phase, CFGO has three types of magnetic domains whose wave vectors of $(q, q, \frac{3}{2})$, $(-2q, q, \frac{3}{2})$ and $(q, -2q, \frac{3}{2})$ are crystallographically equivalent to each other, because of the trigonal symmetry of the crystal.

We have recently discovered 'electric polarization memory effect' in CFGO [2]. When the sample is cooled under applied electric field ($E$) down to 2 K, macroscopic $P$ is observed to emerge. After the 1st cooling, the sample is heated up above 8 K, and cooled again down to 2 K without $E$. In spite of the absence of $E$, the sample shows macroscopic $P$ in the 2nd cooling.

To investigate the mechanism of the memory effect, we have measured asymmetry between the volume fractions of the LH- and RH-helical magnetic domains after the 1st and 2nd cooling, by means of polarized neutron diffraction measurement, by which we can determine contributions to macroscopic $P$ from each domain.

We have applied silver paste electrodes onto the widest surfaces perpendicular to the [110] direction of the single crystal CFGO sample. We used the triple-axis neutron spectrometer PONTA installed by University of Tokyo at JRR-3. The polarization vector of the incident neutron, $\boldsymbol{p}_{\mathrm{N}}$ was set to be parallel or antiparallel to the scattering vector, $\boldsymbol{\kappa}(= \boldsymbol{k}_i - \boldsymbol{k}_f)$, by a guide-field of a helmholtz coil and a spin flipper.

When the sample was cooled under applied $E$, we observed asymmetry of the spin-helicity in both of the magnetic domains having $q$-vectors of $(q, q, \frac{3}{2})$ and $(q, -2q, \frac{3}{2})$, as shown in Figs.1(c-1) and 1(c-2). After the 2nd cooling, we observed the asymmetry even without $E$. Interestingly, the ratio between the asymmetries of the two domains are slightly different from that in the 1st cooling. This result excludes the possibility that the origin of the memory effect is residual charge on the electrodes, which must generate an uniform electric field just like the external electric field applied in the 1st cooling. More detailed analysis will be presented elsewhere.

## References

[1] T. Nakajima *et al.*: PRB **79** 214423(2009).

[2] S. Mitsuda *et al.*: JPCS **404** 2532 (2009).

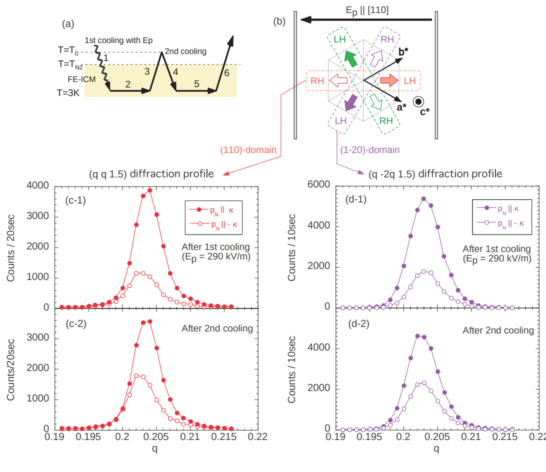


Fig. 1. (a) Temperature sequence of the measurements of the memory effect. (b) Relationships among the directions of $P$ in each domain and the direction of the electric field. [(c-1)-(d-2)] The profiles of the polarized neutron diffraction measurements.