Nonmagnetic impurity effect in ferroelectric phase of $CuFeO_2$

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In the past several years, a magnetic oxide $CuFeO_2$ (CFO) has been intensively investigated as a new class of magnetoelectric (ME) multiferroics, whose ferroelectricity is originated from a proper-screw type magnetic ordering. The recent experimental studies have revealed that the ferroelectric helimagnetic phase, which originally shows up as a magnetic-field-induced phase in pure CFO, also shows up as a ground state in slightly diluted $CuFe_{1-x}Al_xO_2$ (CFAO) and $CuFe_{1-x}Ga_xO_2$ (CFGO). Although the origin of the ferroelectricity must be common to CFO, CFAO and CFGO, the reported values of the observed macroscopic electric polarization, P, are rather different from each other. In particular, the previously reported value of P in CFAO ($\sim$ 50μC/m^2) is remarkably smaller than the values in CFO and CFGO (200 $\sim$ 400μC/m^2).

In the present study, we have thus performed polarized neutron diffraction and in-situ pyroelectric measurements on CFAO, in order to answer the question: "What determines the magnitude of P in CFO, CFAO and CFGO systems?". The polarized neutron diffraction measurements on CFAO($x = 0.015$) were carried out at the triple-axis neutron spectrometer PONTA installed by University of Tokyo at JRR-3 in the Japan Atomic Energy Agency(JAEA). Incident polarized neutron beam with energy 34.06 meV was obtained by a Heusller (111) monochromator. The flipping ratio of the polarized neutron beam was $\sim$ 14. The experimental settings and procedures including pyroelectric measurement were the same as those in the previous polarized neutron diffraction measurement on CFAO ($x = 0.02$).[3]

Since our previous work have revealed a one-to-one correspondence between the spin helicity and the polarity of the induced ferroelectric polarization, in the present work, we have deduced asymmetry in the fractions of the left-handed and right-handed helical magnetic ordering from the results of the polarized neutron measurements. We refer to this asymmetry of the spin helicity as D.

Figures 1(a-1) and 1(a-2) show the measured values of D and P as functions of E_p. We found that P and D in CFAO were rather insensitive to E_p. However, we also found that CFAO can achieve P of $\sim$ 250μC/m^2, which is comparable to the values of P in CFO and CFGO, as shown in the inset of Fig. 1(b). This implies that the magnitude of the local electric polarization in CFO system does not reduced by the Al-substitution, but the sensitivity of P to E_p is reduced.

References

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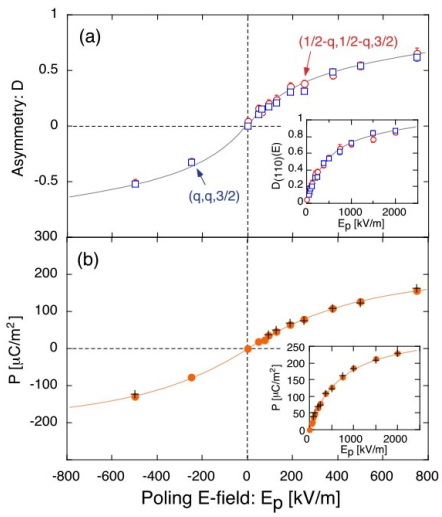

Fig. 1. [(a)-(b)] E_p dependences of (a)P and (b)D in CFAO ($x = 0.015$) at $T = 2.0$K.