Magnetic structure of multiferroics $CeFe_3(BO_3)_4$

Shohei Hayashida, Daiki Kato, Takatsugu Masuda
ISSP The University of Tokyo

Coexistence of magnetic order and electric polarization, *multiferroicity*, has become a top major topic over the past decade in condensed matter physics. Rare-earth ferroborates $R\mathrm{Fe_3(BO_3)_4}$ (R = Y and rare-earth metal show diverse magnetoelectric (ME) effect as a function of the R^{3+} ions [1]. We succeeded in synthesizing high quality single crystal of $CeFe_3(BO_3)_4$ by a flux method. The crystal structure is a trigonal and the space group is $R32$. Although Hinatsu *et al*. reported that a magnetic long range order appeared at $T_\mathrm{N} = 29$ K from specific heat and magnetic susceptibility of polycrystalline sample [2], there is no other report on $CeFe_3(BO_3)_4$. In order to investigate the multiferrocity of $CeFe_3(BO_3)_4$, it is very important to identify the magnetic structure.

We performed neutron diffraction experiment to identify the magnetic structures of the compound. The polycrystalline sample was prepared by a flux method. The mass of the samples was 2.9 g. ECHIDNA diffractometer was used. Ge 331 monochromator was chosen to obtain the neutrons with the wave length of 2.4395 Å. A closed cycle refrigerator was used to achieve 3.7 K as a base temperature. Figure 1(a) shows the diffraction profiles at 3.7 K and 50 K. The nuclear reflection profile is consistent with the crystal structure previously reported. More than 10 additional peaks are observed below 30 K. The intensities of these peaks increase with decrease of the temperature, meaning that they are magnetic Bragg peaks. Figure 1(b) shows the temperature dependence of the diffraction patterns around $2\theta = 27.5^\circ$. There are three magnetic Bragg peaks at $2\theta = 26.8^\circ$, 27.7° and 28.5° in $T = 3.7$ K. The positions of the peaks at $2\theta = 26.8^\circ$ and 28.5° shift to 27.7° with increase of the temperature.

The peak at $2\theta = 27.7^\circ$ is indexed by a propagation vector $\boldsymbol{k}_1 = (0, 0, 1.5)$. The peaks at $2\theta = 26.8^\circ$ and 28.5° are incommensurate peaks and indexed by a propagation vector $\boldsymbol{k}_2 = (0, 0, 1.5 + \varepsilon)$, where value of ε is 0.046 at $T = 3.7$ K and decrease with increase of the temperature. Analyzing the magnetic structure using Rietveld refinement, it is found that the magnetic moments of the Ce^{3+} adn Fe^{3+} ions are aligned in the crystallographic *ab*-plane and antiferromagnetically propagate along the c-axis with $\boldsymbol{k}_1 = (0, 0, 1.5)$. On the other hand, the magnetic moments with $\boldsymbol{k}_2 = (0, 0, 1.5 + \varepsilon)$ construct a proper screw structure along the c-axis. The periodicity of the proper screw structure becomes long with increase of the temperature since the ε decreases with increase of the temperature. The detailed analysis of the magnetic structure is now in progress.

References

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[2] Y. Hinatsu *et al*., J. Solid State Chem. **172**, 438 (2003).

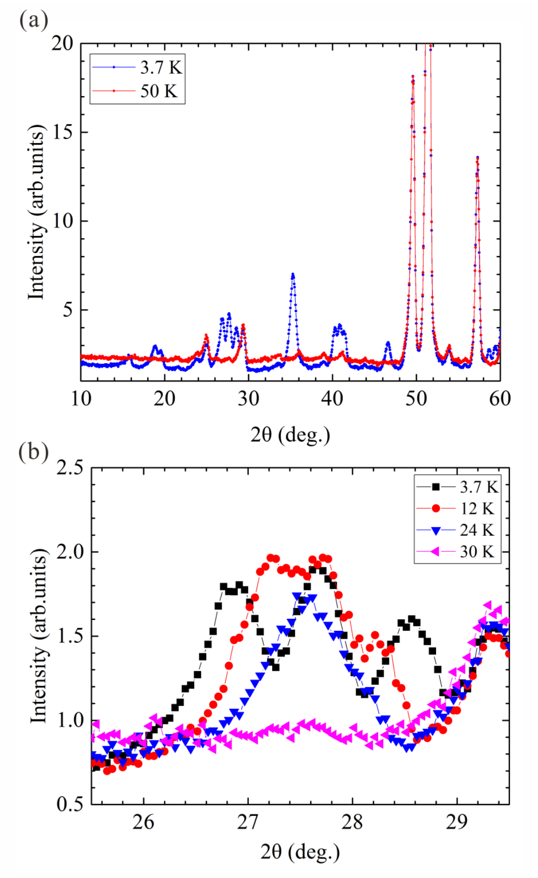

Fig. 1. (a) Neutron diffraction profiles at $T = 3.7$ K and 50 K. (b) A temperature dependence of the diffraction patterns around $2\theta = 27.5°$.