Crystallography

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Determination of magnetic helices in $BaTiCoFe_{10}O_{19}$ by resonant X-ray magnetic scattering

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Introduction

M-type barium hexaferrite, $BaFe_{12}O_{19}$ is ferrimagnetic below T_c = 723 K. The magnetic structure can be described with the spin collinear model, where all the magnetic moments are ordered parallel or antiparallel to *c* axis [1]. Ti^{4+} and Co^{2+} substitution for Fe^{3+} results the reduction of the strong uniaxial magnetic anisotropy. In the solid solution including Ti^{4+} and Co^{2+} ions, the neutron diffraction studies have revealed the existence of a magnetic helix propagated along the hexagonal *c* axis in $BaTi_{0.8}Co_{0.8}Fe_{10.4}O_{19}$ [2]. In this study, by using resonant X-ray magnetic scattering (RXMS) [3,4], the mechanism of the magnetic anisotropy change has been studied for M-type $BaTiCoFe_{10}O_{19}$ hexaferrite.

Experimental

Powder crystals of $BaCoTiFe_{10}O_{19}$ were synthesized by the conventional solid-state reaction using starting materials of $BaCO_3$, $2CoCO_3{\cdot}3Co(OH)_2$, Fe_2O_3 and TiO_2 [5]. The single crystals were synthesized by a flux method. The cell dimensions are a = 5.8955(3), c = 23.205(2) Å ($P6_3/mmc$). Diffraction experiments were carried out at the Fe *K* absorption edge at BL-6C and BL-10A. The Si(111) monochromatized x-rays were guided into a synthetic single crystal of (001) diamond with a thickness of 0.492 mm in order to produce circularly polarized ones.

A four-circle geometry at the BL-6C was used for the RXMS study at 100 K. Low-temperature experiments were performed with the Oxford Cryostream Cooler, where cold and dry nitrogen gas is directly blown onto the crystal. Intensity measurements were made by an ω step-scan technique.

Results and discussion

X-ray diffraction experiments for $BaCoTiFe_{10}O_{19}$ were made at a wavelength of λ = 1.7406 Å (E = 7122.8 eV) at the Fe *K* edge, based on the characteristic XMCD signals for the crystals. A magnetic reflection noted 0 0 8+(2/3) was observed at 100 K.

The estimation of magnetic scattering factors was made with the structure-refinement procedure. A full matrix least-squares method with RADY was applied using 27 independent reflections of end-member $BaFe_{12}O_{19}$. Based on the Gorter model and the residual-factor analyses for $BaFe_{12}O_{19}$, the values of f''_m = 0.23 and f'_m = 0 were finally obtained [6].

Magnetic crystal structures were determined with an asymmetrical ratio ΔR [= $(Y^+ - Y^-) / (Y^+ + Y^-)$], where Y^+ and Y^- are the scattering intensities for left- and right-circular polarizations, respectively. The observed asymmetrical ratio ΔR_{obs} was obtained through the RXMS experiments. The RXMS analyses were made in line with the following procedures: (1) intensity correction by the use of background intensity, (2) estimation of R^+ and R^- from the circularly-polarized integrated intensity, (3) geometrical correction, (4) estimation of ΔR_{obs} from R^+ and R^-, (5) calculation of ΔR_{calc} and (6) magnetic structure determination for individual sites based on the residual factors of $\Sigma(\Delta R_{obs} - \Delta R_{calc})^2$, where the summation is over all reflections used. Final spin orientations are schematically shown in Fig. 1.

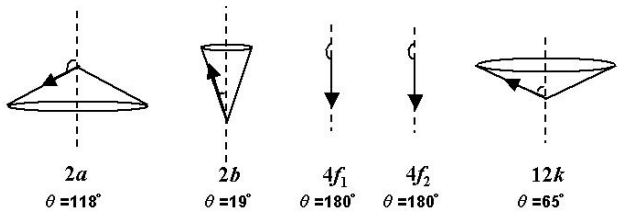

Fig. 1, Schematic presentation of the magnetic structure for five independent Fe sites in a hexagonal $BaCoTiFe_{10}O_{19}$ ferrite. Fe sites are tetrahedral $4f_1$, bipyramidal $2b$, and octahedral $2a$, $4f_2$ and $12k$ sites.

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