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Magnetic Helices in Ba-(TiCo)-Ferrite Determined by the RXMS Method

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Introduction

The crystal structure of hexagonal M-type barium ferrite $BaFe_{12}O_{19}$ has a sequence of spinel *fcc* blocks of $(Fe_6O_8)^{2+}$ and *hcp* blocks of $(BaFe_6O_{11})^{2-}$, where there are a tetrahedral $4f_1$, a bipyramidal 2*b*, octahedral 2*a*, $4f_2$ and 12*k* sites. Although the magnetism is strongly uniaxial along the *c* axis [1], the substitution of Fe ions by different-valence ions such as Ti and Co results in the reduction of the axial anisotropy [2,3]. Since the substitution weakens the anisotropy, we aim to determine the magnetic structure with the spin orientations for the five cation sites of $BaCoTiFe_{10}O_{19}$ by a combination study of site-occupancy refinements, x-ray magnetic circular dichroism (XMCD) and resonant x-ray magnetic scattering (RXMS).

Experimental

Single crystals of $BaTiCoFe_{10}O_{19}$ were used for XMCD and RXMS experiments with a Si(111) double-crystal monochromator and a diamond (001) phase retarder at BL-6C. Intensity measurements of RXMS were made by ω–2θ scan at wavelengths of (I) λ = 1.7406 Å (E = 7122.8 eV) and (II) λ = 1.7389 Å (E = 7129.6 eV) at the Fe *K* edge. For XMCD measurements, a standard transmission setup was used in the Faraday configuration of rare-earth magnets.

Results and discussion

The spin orientation was estimated based on the difference between observed and calculated asymmetrical ratios, $\Delta R = (Y^+ - Y^-) / (Y^+ + Y^-)$, where Y^+ and Y^- are the scattering intensities for left- and right-circular polarizations, respectively. The asymmetrical ratio was observed for 20 Bragg reflections through the RXMS measurements. The residual factors of $\Sigma(\Delta R_{obs} - \Delta R_{calc})^2$ was used in the least-squares calculations to determine the inclination of magnetic moments as a function of the multiplicity m_i to be the coefficient of atomic scattering factor. Since each of five Fe sites has a minimum on the multiplicity as seen in Fig. 1, it is possible to estimate the canting of magnetic moments. The sharp opening of a parabola gives the good convergence in the calculations.

The calculation of the asymmetrical ratio was based on the equation of

$$\Delta R_{calc} \cong 2\tan 2\theta \frac{(F_0 + F')F_m'' - F''F_m' - F''F_{0,m}}{|F_{calc}|^2}.$$

The symbols of F_0, $F_{0,m}$, F', F'', F'_m and F''_m are the structure factors related to Thomson, magnetic, real and imaginary parts of anomalous scattering and resonant magnetic scattering, respectively. A canting angle θ of each spin of $BaTiCoFe_{10}O_{19}$ was determined by using the minimum values of m_i for five Fe sites in the calculation of residual factors $\Sigma(\Delta R_{obs} - \Delta R_{calc})^2$.

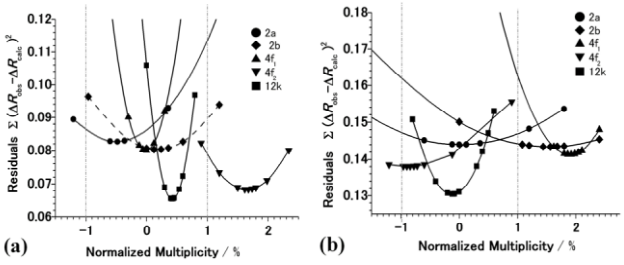

Fig. 1: Residual factors as a function of the multiplicity m_i in (a) wavelength I and (b) II measurements.

The canting deeply depends on the site-preference of Ti and Co ions. Since the Energy (I) at the threshold of the absorption edge is interpreted as Fe^{3+} origin, the results were assigned to the octahedral 2*a*, $4f_2$ and 12*k* sites. The Energy (II) may represent the magnetic information on the $4f_1$ site with the coordination number of four. The 2*b* site with five-coordinated Fe^{3+} includes both magnetic effects measured at Energies (I) and (II). The information on cation distributions in $BaTiCoFe_{10}O_{19}$ was referred to the results from single-crystal x-ray diffraction work [4]. The canting angles thus evaluated for $4f_1$, 2*b*, 2*a*, $4f_2$ and 12*k* sites are 180°, 19°, 118°, 180° and 65°, respectively. The magnetic structure obtained in this study is close to the reported one by the neutron diffraction study [2], although the magnitude of canting angles is somewhat different and the spin orientation of the 2*a* site is reversal.

References

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