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$_2$O$_3$)$_n$ and hcp blocks of (BaFe$_{6}$O$_{8}$)$_n$, where there are a tetrahedral 4f$_t$, a bipyramidal 2b, octahedral 2a, 4f$_i$ and 12k 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 different-valence ions such as Ti and Co results in the axis [1], the substitution of Fe ions by along the c

The symbols of $F'_0$, $F''_0$, $F'_m$, $F''_m$ 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 $\theta$ of each spin of BaTiCoFe$_{12}$O$_{19}$ was determined by using the minimum values of $m_i$ for five Fe sites in the calculation of residual factors $\Sigma(\Delta R_{obs} - \Delta R_{calc})^2$.

Experimental

Single crystals of BaTiCoFe$_{12}$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 $\omega$-2$\theta$ scan at wavelengths of (I) $\lambda = 1.7406$ Å ($E = 7122.8$ eV) and (II) $\lambda = 1.7389$ 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

$$\Delta R_{calc} \cong 2 \tan \theta \left( \frac{(F'_0 + F')F'_m - F''_m F''_m}{F_{calc}^2} \right).$$

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 2a, 4f$_i$ and 12k sites. The Energy (II) may represent the magnetic information on the 4f$_t$ site with the coordination number of four. The 2b site with five-coordinated Fe$^{3+}$ includes both magnetic effects measured at Energies (I) and (II). The information on cation distributions in BaTiCoFe$_{12}$O$_{19}$ was referred to the results from single-crystal x-ray diffraction work [4]. The canting angles thus evaluated for 4f$_t$, 2b, 2a, 4f$_i$ and 12k 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 2a site is reversal.

References


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