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Resonant soft x-ray diffraction study of $SrFe_{1-x}Co_xO_3$ thin films

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1 Introduction

Topological spin textures have attracted considerable attention because of their potential for novel quantum transport phenomena and spintronic functions. One such example is a skyrmion spin texture. The formation of skyrmion crystal structure in B20-type compounds was already observed in real space by using Lorentz transmission microscopy [1]. B-20 type compounds have a chiral cubic (cubic but noncentrosymmetric) lattice. Helical magnetic structures are mediated by Dzyaloshinskii-Moriya interactions.

Among the centrosymmetric oxides, helimagnetic ordering was reported for $SrFeO_3$. Recently, high-quality thin films of $SrFeO_3$ and $SrFe_{0.99}Co_{0.01}O_3$ have become available. In this study, we performed resonant soft x-ray diffraction measurements to determine the magnetic structure of these thin films. Resonant soft x-ray diffraction is a very powerful experimental technique to study magnetic structures in small samples including thin films due to giant resonant enhancement at $2p \rightarrow 3d$ absorption edges.

2 Experiment

$SrFe_{1-x}Co_xO_3$ (x = 0, 0.01) thin films were fabricated by pulsed laser deposition technique. Resonant soft x-ray diffraction measurements were performed at BL-16A in Photon Factory, KEK, Japan. A continuous helium-flow cryostat allows measurements between 30 and 300 K. The incident photon energy was tuned to the Fe L_3 edge (708 eV). The polarization of the incident x ray was circular, and we obtained the same results from right- and left-handed circular polarization.

3 Results and Discussion

Figure 1 shows the $\boldsymbol{Q}$ = (q q q) magnetic diffraction peaks observed by resonant soft x-ray diffraction. The helical magnetic peaks were observed along the (111) direction in thin films as well as in bulk. The Q value in the $SrFeO_3$ thin film is similar to tha in bulk $SrFeO_3$, indicating that helical magnetic structures similar to those bulk are formed in thin films. However, the temperature where magnetic peaks appear, T_N, for the $SrFeO_3$ thin film (= 106 K) is lower than that for bulk $SrFeO_3$ (T_{N3} = 130 K) and rather close to T_{N2} for bulk $SrFeO_3$ (110 K) [2]. In $SrFe_{0.99}Co_{0.01}O_3$, the situation is similar, that is, the T_N for thin films is lower than bulk T_{N3} and rather close to bulk T_{N2}. These results indicate that phase III, where simple proper screw magnetic structures are considered to be formed in bulk samples, may not exist in thin films.

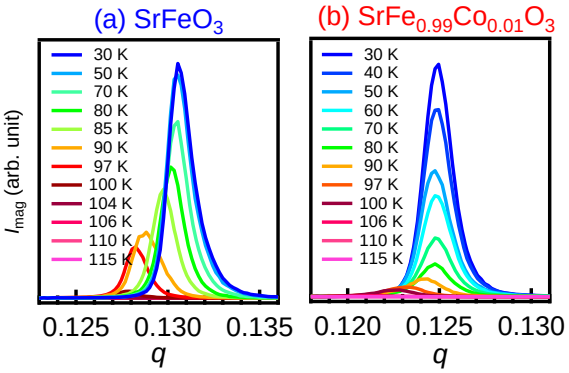

Fig. 1: $\boldsymbol{Q}$ = (q q q) magnetic diffraction peaks of $SrFe_{1-x}Co_xO_3$ (x = 0, 0.01) observed by resonant soft x-ray diffraction measurements.

The magnetic periodicities of the helical spin structure are 1.7 nm and 1.8 nm for thin films of $SrFeO_3$ and $SrFe_{0.99}Co_{0.01}O_3$, respectively. The periodicity becomes longer as Co concentration increases, which is similar to the case of bulk [3].

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