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Observation of spin structure in $CrNb_3S_6$ by means of resonant soft x-ray scattering

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We clarified a formation of chiral magnetic soliton lattice in mono-axial chiral magnet $CrNb_3S_6$ as seen via small-angle resonant soft x-ray scattering (RSXS) near the Cr *L*-absorption edge. In our results, the magnetic-field dependence of the higher harmonic magnetic diffraction and that of chiral magnetic soliton lattice constant are found to agree well with a theoretical magnetic structure predicted based on the chiral XY-spin model. We also observe deformations of the spin structure from the predicted chiral magnetic soliton lattice near the critical temperature.

1 Introduction

$CrNb_3S_6$ is one of the chiral magnets, and forms chiral soliton lattice (CSL) by applying small magnetic fields perpendicular magnetic modulation vector along *c*-axis. It has been investigated by theory and by magnetic, electric transport properties measurements on single crystals.[1,2] In order to study the magnetic-field dependence of the magnetic structure for the CSL in more detail, we performed a small-angle RSXS.

2 Experiment

A single crystal of $CrNb_3S_6$ with a volume of ~0.01 mm^3 was grown by the chemical vapor transport method.[3] A thin plate with a thickness of ~120 nm for small-angle RSXS observation was prepared by the focused ion beam (FIB) thinning method (SMI3200; Seiko Instruments Inc., Japan). The sample was affixed with carbon contacts on a Si substrate with a square hole of 10 × 10 μm^2. Small-angle RSXS measurements were carried out at BL-16A. An in-vacuum CCD camera (2024 × 2024 pixels, Roper Industrial Inc.), positioned downstream of the sample, was used to record the RSXS intensity.

3 Results and Discussion

Figure 1(a) shows the experimental setup for the transmitted small-angle RSXS measurements. Figure 1(b) displays the CCD image measured at 195 mT with the circularly polarized soft x-ray of 577 eV at 80 K. An application of magnetic fields induces higher harmonic magnetic peaks. Finally, 7 spots are discerned with q = ±0.052, ±0.107, ±0.154 and 0.207 nm^{-1} at 195 mT [see Figs. 1(b,c)]. Magnetic-field dependence of q is consistent with a predicted theoretical curve based on the chiral XY-spin model including the correction of the demagnetizing field, which strongly depend on the shape of the specimen and is proportion to the magnetization. Near the critical temperature (T_C ~119.6 K), the dependence deviates from the theoretical curve with the correction. Additionally, according to the temperature dependence of FWHM of q, the magnetic correlation of helix becomes short-range order (SRO) above T_C. We are able to define two kinds of phases; Helix < T_C ~119.6 K < SRO helix < T_{SRO} ~121.6 K. In the SRO phase, it indicates that FM order and short-range modulation due to DM interaction emerges.

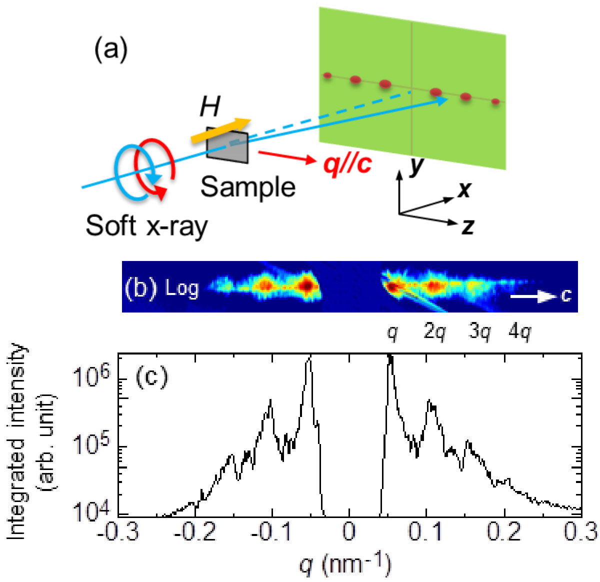

Fig. 1: (a) A transmission-type setup for small-angle RSXS. (b,c) CCD images of small-angle RSXS, and the profiles of it for CSL phase, respectively.

References
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