16A/2009S2-008

Resonant soft X-ray scattering study of magnetic structures in $La_{1.5}Ca_{0.5}CoO_4$

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Introduction

$La_{2-x}Ca_xCoO_4$ system has been controversial for its Co^{3+} spin states. Co^{2+} always takes high-spin (HS) states, but Co^{3+} may take various spin states, estimated from magnetization measurements; HS for x < 0.5 and intermediate-spin (IS) for x > 0.7 [1]. $La_{2-x}Ca_xCoO_4$ takes two kinds of magnetic structures below Neel temperature (T_N ~ 50 K) with scattering vector q = (1/2,0,1/2) and (1/2,0,1). For x < 0.5 only (1/2,0,1/2) structure is observed, and for x > 0.5 only (1/2,0,1) structure is observed by neutron scattering [2]. For x = 0.5 both magnetic structures with q = (1/2,0,1/2) and (1/2,0,1) are observed. Therefore, it is important to reveal the difference of magnetic structures with q = (1/2,0,1/2) and (1/2,0,1) and their relationship with Co-site electronic structures. Resonant soft X-ray scattering at transition-metal L edge is sensitive to the magnetic moment of transition-metal d electrons and is a powerful technique to investigate the magnetic ordering with high sensitivity and to study its relationship with electronic structures.

Experimental and Results

Experimental

Monocrystalline samples of $La_{1.5}Ca_{0.5}CoO_4$ were prepared. [100] surface was cut out and was polished to make mirror-like surface. We set the *ac* plane as the scattering plane to measure the magnetic ordering with q = (1/2,0,1/2). We measured resonant soft X-ray scattering at Co $L_{2,3}$ edge at BL16A of Photon Factory.

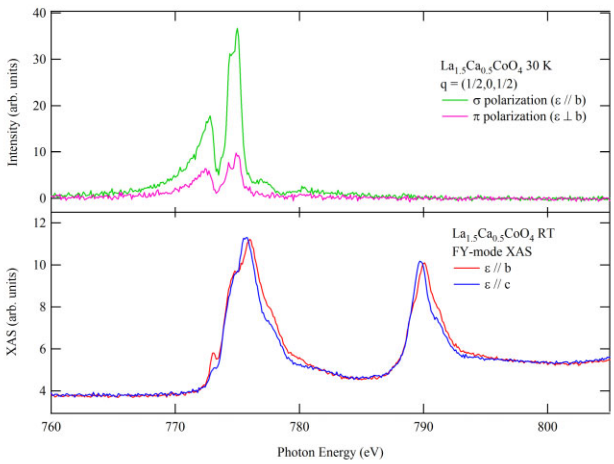

Fig. 1: Fix q scans with q = (1/2,0,1/2) under σ and π polarization at 30 K (upper panel) and fluorescence-yield XAS under ε // b and // c at RT (lower panel) of $La_{1.5}Ca_{0.5}CoO_4$.

Results

Magnetic ordering peaks are successfully observed by Co $L_{2,3}$ resonant X-ray scattering below 55 K. Figure 1 shows the energy scans with fixed q at (1/2,0,1/2) of $La_{1.5}Ca_{0.5}CoO_4$ at 30 K. In comparison with the fluorescence-yield XAS, sharp structures are observed at the energy levels of the Co L_3 XAS peak, but no significant structures can be seen at Co L_2 XAS peak. As for the polarization dependence of resonant magnetic scattering [3], intensity of magnetic ordering with q = (1/2,0,1/2) under σ polarization (ε // b) is 2-3 times stronger than that under π polarization (ε ⊥ b).

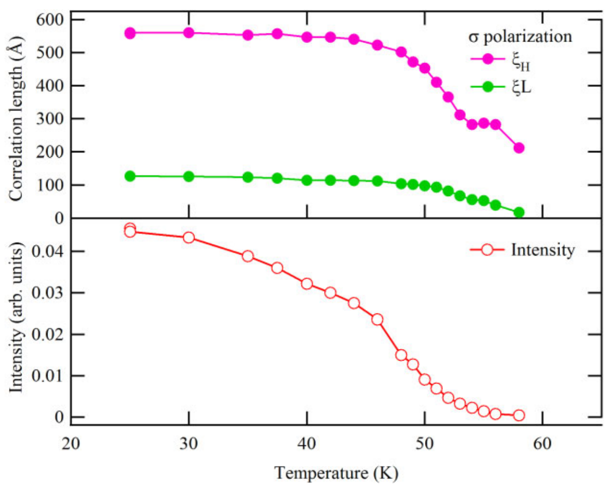

Fig. 2: Temperature dependence of correlation length defined as 1/HWHM of *H and L* scans and intensity of magnetic structure with q = (1/2,0,1/2) under σ polarization.

Setting the photon energy at 773 eV, we have measured the fine temperature dependence of magnetic structure in q scans along q_x (H scan) and q_z (L scan). Figure 2 summarizes the temperature dependence of correlation length ξ_H (along a) and ξ_L (along c) and intensity of magnetic structure with q = (1/2,0,1/2). Correlation lengths are defined as 1/HWHM of H and L scans, fitted by a Lorentz function. Magnetic ordering disappears above 55 K and correlation length along a is much longer than that along c, which reproduces well with the neutron scattering results [1].

References

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