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Orbital Ordering in Room Temperature Ferromagnet $Sr_3YCo_4O_{10.5}$ Studied by a Resonant X-ray Scattering

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Introduction

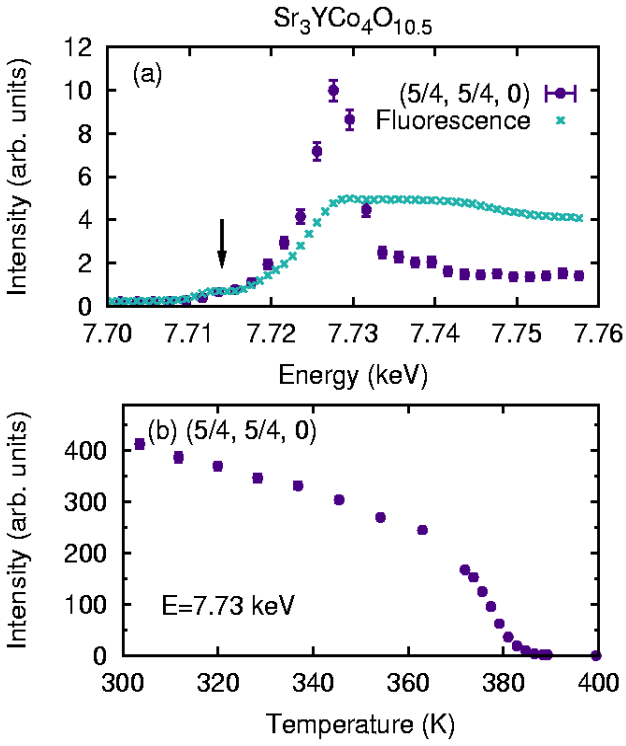
New trivalent Co oxide, $Sr_{1-x}R_xCo_4O_{10.5}$ (R=Y and lanthanide, 0.2<x<0.25) has been found recently as a room temperature ferromagnet with a Curie temperature Tc~370K, which is the highest Tc among perovskite Co oxides [1]. In spite of the remarkable high Tc, the ferromagnetic order is fragile against a small substitution of Mn for Co. Hence, the origin of ferromagnetism was expected to be unconventional. They suggested that the origin is the e_g orbital ordering of Co^{3+} intermediate state (IS: $t_{2g}^5e_g^1$). The crystal structure was studied by a powder x-ray diffraction [2]. The basic structure is formed with the CoO_6 octahedral and $CoO_{4.25}$ layers, which stack along c axis alternatively. The orbital state of the CoO_6 octahedron was evaluated from the anisotropy of the Co-O bond length in the ferromagnetic phase. They insisted that the e_g orbital ordering of the IS state is an origin of the ferromagnetism. In this study, we have investigated the orbital ordering of Co^{3+} ($3d^6$) ion using a resonant x-ray scattering (RXS) technique.

Experiments

The single crystal of $Sr_3YCo_4O_{10.5}$ was used for this experiment. The (110) surface of a sample was polished with fine emery paper so as to measure the azimuthal angle dependence of the RXS signal. The RXS experiments were performed by four-circle diffractometers at beam lines 4C and 3A of the Photon Factory. The incident beam was monochromatized by a pair of Si(111) crystals, giving an energy resolution about 2 eV, and focused by a bend cylindrical mirror. The x-ray energy near the Co K-edge (~7.72 keV) was utilized for measuring the RXS signal. The furnace was used for the high temperature experiment (T=300-500 K).

Results

The RXS signal was searched for the determination of the Co^{3+} orbital state. The RXS signal was found at (5/4, 5/4, 0) as shown in Fig. (a); the reflection is indexed using the unit cell 2ax2ax4a, where a is the lattice constant of the perovskite unit cell. The signal resonates only near Co K-edge energy, which can be evaluated by the fluorescence spectrum as shown by cross in the figure. The azimuthal angle dependence of the RXS intensity exhibits two-fold symmetry. These results elucidate that the anisotropy exists in the Co sites and the antiferro-type anisotropic Co site ordering forms in the ferromagnetic phase. Moreover, we found the weak RXS signal at the Co 1s-> e_g transition energy as indicated by the arrow in the figure; the signal implies the presence of an anisotropic e_g orbital. As a result, the orbital ordering of Co e_g orbital and the presence of the IS state can be expected. The temperature dependence of the RXS intensity was measured as shown in Fig. (b). The intensity diminishes with increasing temperature, and vanishes at Tc. The temperature dependence is similar to that of the magnetization. These indicate that the ferromagnetism is caused by the orbital ordering of Co^{3+}. We also determined the orbital ordering structure based on the intensity ratio among the RXS peaks. The obtained orbital structure may explain the ferromagnetism.



References

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