

Valence state in the interface ferromagnet of CaMnO₃/CaRuO₃ superlattice

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Beamline(s): X22C

Introduction: Many kinds of artificial superlattice of perovskite transition-metal oxides have been fabricated and investigated. It is important to understand the physics at the interface or the junction, such as magnetism and transport properties, and to examine a possibility for the application. Recently ferromagnetism was found in a superlattice of CaMnO₃ (CMO) and CaRuO₃ (CRO), though neither CMO (an antiferromagnetic insulator) nor CRO (a paramagnetic metal) are ferromagnets [1]. The magnetization of this superlattice normalized by the number of the interface is constant. The fact indicates that the ferromagnetism occurs only at the interface and could be explained by the valence exchange of $\text{Mn}^{4+} + \text{Ru}^{4+} \rightarrow \text{Mn}^{3+} + \text{Ru}^{5+}$ at the interface, which causes a ferromagnetic double exchange interaction between ($\text{Mn}^{4+}, \text{Ru}^{5+}$) and Mn^{3+} . To determine the valence state of the manganese atom, especially at the interface, we have carried out x-ray diffraction experiments at the K-absorption edge of Mn. The difference of the absorption edge of Mn^{3+} and Mn^{4+} is reflected in the difference of the anomalous scattering factors, and makes it possible to distinguish the valence state.

Methods and Materials: The sample consists of 10 unit cells of CMO and 8 unit cells of CRO which were deposited 15 times on the LaAlO₃ (001) single crystal substrate. The experiments were performed at the beamline X22C at NSLS and the beamline 16A2 at Photon Factory, KEK, Japan. All the data were measured at room temperature.

Results: In the 00*l*-scan (*l* is represented in the unit of $c \sim 3.8 \text{ \AA}$ cubic perovskite unit cell), we can see the Bragg peaks at $l = n/18$ (*n* is an integer) which corresponds to the 18 times length of the superlattice unit cell. We also measured the energy dependence of some peaks. Figure 1 shows the energy dependence of the peaks at $l = 1+1/18$ and $1+15/18$. The peak intensity was simulated on the one-dimensional step model, including the charge transfer from Ru to Mn, that is, the valence states of $x\text{Mn}^{3+} + (1-x)\text{Mn}^{4+}$ (*x* denotes the amount of charge transfer) at the 1st and 10th layer of CMO and $x\text{Ru}^{5+} + (1-x)\text{Ru}^{4+}$ at the 1st and 8th layer of CRO were considered. Only multiplying the scale factor for each peak, the simulations agree well with the observations. For the peak of $l = 1+15/18$, the simulation of $x=0$ can reproduce the observation better than that of $x=1$.

Conclusions: We have carried out the x-ray diffraction study at the K-absorption edge of Mn for the determination of the valence state of CaMnO₃/CaRuO₃ superlattice. Our results suggest that the amount of charge transfer at the interface is very small and much smaller than one electron, if it exists.

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References:

[1] K. S. Takahashi, M. Kawasaki, and Y. Tokura, "Interface ferromagnetism in oxide superlattice of CaMnO₃/CaRuO₃", *Appl. Phys. Lett.*, **79**, 1324-1326 (2001).

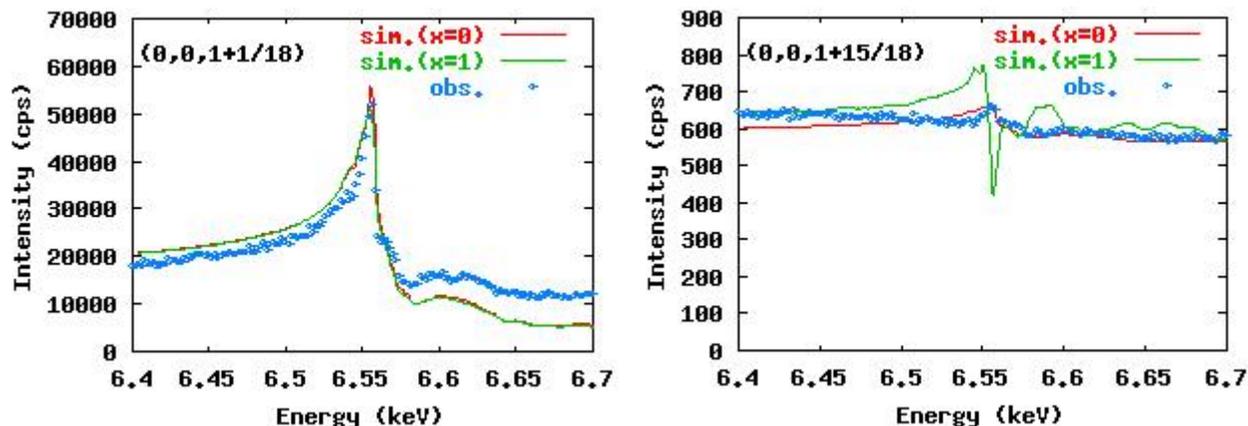


Figure 1: Energy dependence of peak intensity at $l = 1+1/18$ and $1+15/18$. Solid lines and points represent the simulations and the observed data, respectively.