BL-2A/2015G577, 2015S2-005

Electronic states of $SrRu_{0.5}Cr_{0.5}O_3$ epitaxial thin films investigated by soft X-ray absorption and photoemission spectroscopies

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1 Introduction

Transition-metal perovskite oxides (ABO_3) with correlated *d* electron system are interesting because of their wide variety of physical properties. Among them, $SrRuO_3$ is a ferromagnetic metal with Curie temperature of 163 K in a bulk and 152 K in a thin film on $SrTiO_3$ (001) substrate, which are enhanced up to 188 K and 165 K, respectively, with 10% Cr doping into the *B* site [1,2]. Further Cr doping into $SrRuO_3$ changed the electric properties: heavily Cr-doped $SrRuO_3$ generally shows semiconducting behavior and nonlinear lattice volume change, which can be explained by $Ru^{4+} + Cr^{4+} \rightarrow Ru^{5+} + Cr^{3+}$ charge transfer [1]. However, bulk polycrystalline $SrRu_{1-x}Cr_xO_3$ ($x > 0.15$) has been synthesized only at high pressure and there is no report of the single crystals or epitaxial thin films, which are better to investigate intrinsic electronic states with electron spectroscopy. In this study, we fabricated $SrRu_{0.5}Cr_{0.5}O_3$ (SRCO) epitaxial thin films using pulsed laser deposition (PLD) method and investigated their electronic state with soft X-ray absorption and photoemission spectroscopies (XAS and PES).

2 Experiments

SRCO thin films were grown on single crystalline $SrTiO_3$ (111) substrates by PLD method. As a PLD target, Ru-rich $SrRuCr_{0.5}O_{3-\delta}$ was used to compensate the volatilization of Ru during deposition. The substrate temperature (T_s) was varied from 600ºC to 900ºC, while O_2 partial pressure was fixed to 1×10^{-3} Torr, during the deposition run. Crystal structure of the films were characterized by X-ray diffraction (XRD) technique. XAS and PES measurements were conducted at the BL-2A beamline of the Photon Factory, KEK. The XAS spectra were measured using the total electron-yield method. The PES results were calibrated with the Fermi edge of gold in electrical contact with the samples.

3 Results and discussion

Figure 1 (a) shows 2θ-θ XRD patterns of the films fabricated at different T_s. Note that the peak of the film deposited at 800ºC is hidden by the substrate peak. The film deposited at 900ºC has similar out-of-plane lattice constant to the counterpart of bulk (2.25 Å) [1]. Meanwhile, the films deposited at 600ºC and 700ºC have larger out-of-plane lattice constants of 2.30 Å, suggesting the formation of oxygen vacancies. In-plane XRD measurement revealed the coherent growth of the film deposited at 900ºC.

In order to elucidate the valence of *B*-site cations, we performed XAS and PES measurements. Figure 1 (b) shows XAS spectra in the Cr *L*-edge of the film deposited at 900ºC, together with $LaCrO_3$ and $SrCrO_3$ as references of Cr^{3+} and Cr^{4+}, respectively [3]. The spectrum of the SRCO film is similar to that of $LaCr^{3+}O_3$ in peak position and shape, which revealed that a part of Cr ions in the SRCO film is trivalent. In addition, we observed that the Ru 3*p* PES peak of the SRCO film was located at the higher binding energy than that of $SrRu^{4+}O_3$. Therefore, these results indicate $Ru^{4+} + Cr^{4+} \rightarrow Ru^{5+} + Cr^{3+}$ charge transfer in the SRCO film.

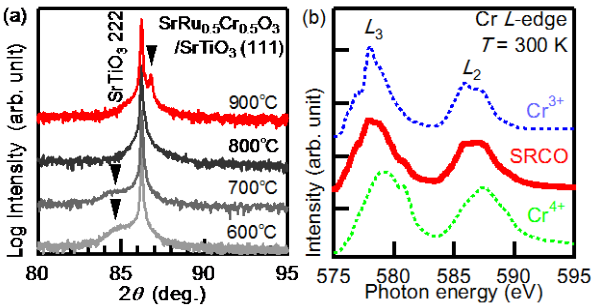

Fig. 1. (a) 2θ-θ XRD patterns of SRCO/$SrTiO_3$ (111) thin films fabricated from Ru-rich target at T_s = 600 – 900°C. Arrows denote the peaks from the films. (b) XAS spectra of SRCO thin film together with $LaCrO_3$ (Cr^{3+}) and $SrCrO_3$ (Cr^{4+}) references [3].

References

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