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# Surface electronic structures of terminating-layer-controlled $La_{0.6}Sr_{0.4}MnO_3$ thin films studied by *in-situ* photoemission spectroscopy

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## Introduction

The half-metallic nature in hole-doped perovskite manganese oxides[1] makes these materials intriguing for potential application to the magnetoelectronic devices.[2-4] However, in spite of 100% spin polarization of their conduction carriers, the performance of thin film tunneling magnetoresistance is far below what is expected.[2-4] The fact suggests the importance of the surfaces and interfaces; since perovskite oxides represented by the fomula $ABO_3$ consist of AO (A-site plane) and $BO_2$ (B-site plane) atomic layers, alternatively stacked along the *c*-axis direction, it is important to investigate the difference of surface electronic structures between two different terminating-layers. In this study, we have investigated the surface electronic structures of A($La_{0.6}Sr_{0.4}O$)- and B($MnO_2$)-site terminated $La_{0.6}Sr_{0.4}MnO_3$ (LSMO) thin films grown epitaxially on $SrTiO_3(001)$ substrates by laser molecular beam epitaxy (laser-MBE) in terms of *in-situ* synchrotron-radiation photoemission spectroscopy.

## Experimental

The termination-layer-controlled LSMO thin films were grown in a laser-MBE chamber connected to a synchrotron radiation photoemission system at BL1C of the Photon Factory.[5] The terminating layer of the $La_{0.6}Sr_{0.4}MnO_3$ films was changed from B to A site by inserting one atomic layer of SrO between the $La_{0.6}Sr_{0.4}MnO_3$ film and a wet-etched $TiO_2$-terminated $SrTiO_3(001)$ substrate.[6] The successful control of the terminating layer was confirmed by measuring the angular dependence of core-level spectra.[7] The film was transferred to the photoemission chamber under vacuum of $10^{-10}$ Torr. The PES spectra were taken at 150 K with the total energy resolution of about 300 meV at the photon energy of 270 eV.

## Results and Discussion

Figure 1 shows Sr 3*d* core-level PES spectra for A-site terminated LSMO (LSMO/SrO/STO) and B-site terminated LSMO (LSMO/STO) films at two different emission angles $\theta = 0°$ and 60°. The Sr 3*d* spectra show noticeable and quantitative difference between two films, reflecting their electronic structures in the surface region. More detailed information on these Sr 3*d* spectra can be obtained by curve fitting, as shown in Fig. 1. It is clear that the Sr 3*d* core level consists of three components labeled $B_A$, $S_A$, and $S'_A$ for LSMO/SrO/STO while only two major components, $B_B$ and $S_B$, are visible in the spectra of LSMO/STO. The reduced intensities of the $B_A$ and $B_B$ components under surface-sensitive conditions ($\theta = 60°$) indicate that these components originate from the Sr atoms in a La/SrO layer below a $MnO_2$ plane. On the other hand, the opposite angular behavior of other components ($S_A$, $S'_A$, and $S_B$) indicates their surface origin.

By taking into account the different terminating layers of the two films, we assign the second doublet $S_A$ with the chemical shift (CS) values of 0.68±0.01 eV in LSMO/SrO/STO to Sr atoms in the uppermost La/SrO layer. On the other hand, in LSMO/STO, the surface component of $S_B$ is attributed to the presence of Sr atoms on the $MnO_2$ terminating layer. The presence of Sr atoms may originate from the thermodynamic surface-segregation and/or residual Sr atoms migrating at the surface during deposition.

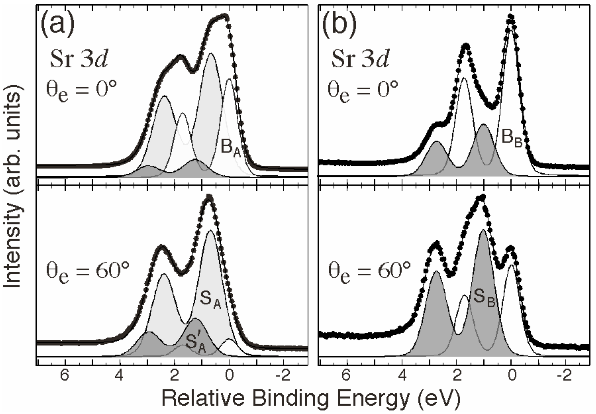

Fig. 2. Sr 3*d* core-level spectra and their decompositions for (a) LSMO/SrO/STO and (b) LSMO/STO.

## References

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