

Potential profiling in depth for perovskite oxide heterojunctions using photoemission spectroscopy

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Introduction

Perovskite oxide (ABO_3) heterojunctions produce some distinctive interfacial electronic states, such as interfacial metallic conductivity, ferromagnetic nature, and superconductivity [1-3]. The oxide heterojunction grown in the (001) direction has two types of interfacial structures. Consequently, these distinctive interfacial electronic states are strongly depending on the interfacial terminating layer [1]. Since the modulation of electric potential in the interface region considerably affects the junction characteristics, it is indispensable precisely to determine their band diagrams, in particular the potential profile in depth, for considering the interfacial structure.

In this study, we have performed a photoemission spectroscopy (PES) analysis to directly determine the potential distribution in depth of promising oxide heterojunctions for promising oxide heterojunctions: $La_{0.6}Sr_{0.4}MnO_3$ (LSMO) /Nb-doped $SrTiO_3$ (Nb:STO) having different interfacial terminating layers and $SrRuO_3$ (SRO) /Nb:STO heterojunctions. Through a comparison between the properties of these heterostructures, we discuss the distinctive interfacial electronic states occurring at oxide heterojunctions.

Experimental

Samples were fabricated in a laser molecular beam epitaxy chamber connected to a synchrotron-radiation photoemission system at BL-2C. The Nb:STO substrate was annealed at 1050 °C and an oxygen pressure of 1×10^{-7} Torr to ensure an atomically flat TiO_2 layer terminated surface. During LSMO and SRO depositions, the substrate temperatures were 1000 °C and 750 °C and the ambient oxygen pressures 1×10^{-4} Torr and 1×10^{-3} Torr, respectively. After deposition, these samples were subsequently annealed at 400 °C for 45 min and under atmospheric pressure of oxygen to fill residual oxygen vacancies. The film thicknesses were controlled on an atomic scale by monitoring the intensity oscillations of the reflection high-energy electron diffraction specular spot during growth. The PES spectra were taken with a total energy resolution of 150 meV in the photon energy of 800 eV at BL2C of KEK PF, and with that of 230 meV in 8 keV at BL47XU of SPring-8.

Results and discussion

The tunability of probing depth of PES ranging from 0.1 nm to 10 nm enables us to obtain the potential profile in depletion layers formed at the interface. The obtained potential profiles in depth for the (a) LSMO/ TiO_2 -Nb:STO and (b) LSMO/SrO-Nb:STO and SRO/Nb:STO heterojunctions are illustrated in Fig. 1. The precise depth profiling analysis of LSMO/ TiO_2 -Nb:STO interfaces with $-La_{0.6}Sr_{0.4}O/TiO_2/SrO-$ structure reveals the existence of a certain thin depletion layer of 1-2 nm with an abrupt potential drop near the interface. On the other hand, the ideal depletion layer is formed for LSMO/SrO-Nb:STO and SRO/Nb:STO interfaces with $-SrO/TiO_2/SrO-$ terminating layer. These results suggest that the adjacency of TiO_2 layer with different AO layers at the interface is responsible for the formation of the thin depletion layer with an abrupt potential drop near the interface.

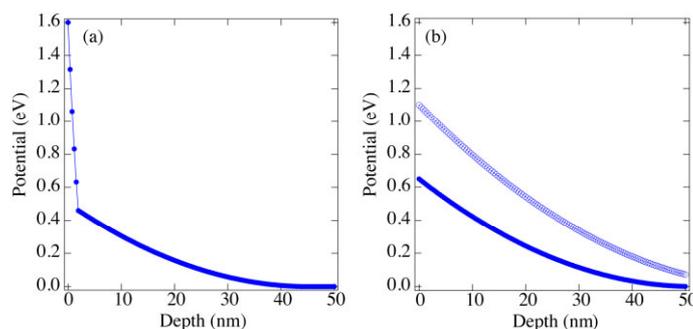


FIG. 1. : The potential profiles in depth deduced from the present PES measurements for (a) LSMO/ TiO_2 -Nb:STO and (b) LSMO/SrO-Nb:STO (filled circle) and SRO/Nb:STO (open circle) Schottky junctions.

References

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