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Termination dependence of the Schottky barrier height for $La_{0.6}Sr_{0.4}MnO_3$/Nb:$SrTiO_3$ heterojunctions

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Introduction

The height of the Schottky barrier (Φ_B) that forms at a metal/insulator junction is an essential and fundamental parameter that dominates the device performance. A perovskite oxide heterojunction (ABO_3/A'B'O_3) has two types of interfacial structures that are AO/BO_2//A'O/B'O_2 and BO_2/AO//B'O_2/A'O layer sequences, and consequently different interfacial electronic structures emerge depending on the interfacial termination [1]. Thus, the precise determination of the band diagrams for interfacial temination-layer controlled oxide heterojunctions is indispensable for designing spintronic devices, such as tunneling magnetoresistance devices using a half-metallic ferromagnetic material like $La_{0.6}Sr_{0.4}MnO_3$ (LSMO).

In this study, we report on the band diagrams of interfacial termination-layer controlled a half-metallic ferromagnetic oxide LSMO/Nb doped $SrTiO_3$ (Nb:STO) heterojunctions determined by *in situ* photoemission (PES) studies.

Experimental

LSMO/TiO_2-Nb:STO and LSMO/SrO/Nb:STO (*n*-type and *p*-type LSMO/Nb:STO, respectively) heterojunctions 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 ºC and an oxygen pressure of 1×10^{-7} Torr to ensure an atomically flat TiO_2 layer terminated surface. For *p*-type structure, we initially deposited SrO on the TiO_2-terminated Nb:STO substrate to change its termination from the TiO_2 to SrO layer. During LSMO depositions, the substrate temperatures and the ambient oxygen pressures were 1000 ºC and 1×10^{-4} Torr, respectively. 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 *in situ* a total energy resolution of 150 meV in the energy range of 600 to 800 eV. The work functions (ϕ_m) and electron affinities (χ_i) were determined from the secondary electron emission spectra recorded with the He I (21.2 eV) resonance line.

Results and discussion

The measurement of core-level spectra enables us to determine Φ_B formed at the heterojunctions directly. For both junctions, a peak shift towards a lower binding energy was clearly observed as the overlayer film thickness increased. Judging from the saturation level of the peak shift, Φ_B could be estimated to be 1.2 ± 0.1 and 0.6 ± 0.1 eV for the *n*-type and *p*-type heterojunctions, respectively. The band diagrams for the (a) *n*-type and (b) *p*-type LSMO/Nb:STO heterojunctions derived from the present PES experiments, are illustrated in Fig. 1. Φ_B of *n*-type LSMO/Nb:STO is much *higher* than the prediction from the Schottky-Mott rule (ϕ_m - χ_i) by 0.5 eV, indicating the formation of an "interface dipole" [2]. In contrast, for *p*-type LSMO/Nb:STO, Φ_B is *lower* by 0.4 eV. These results suggest that the direction of the interface dipole is inverted by changing the termination layer owing to the inversion of the polarity discontinuity at the polar/nonpolar interface.

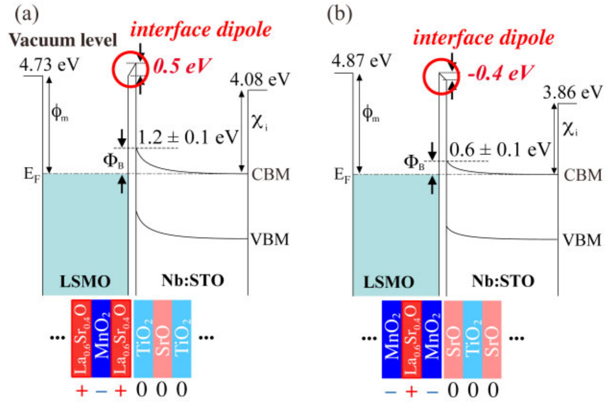

FIG. 1. : Band diagrams derived from the present *in situ* PES measurements for (a) *n*-type and (b) *p*-type LSMO/Nb:STO Schottky junctions.

References

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