Band diagram of a p-n junction between Mott-insulator LaMnO$_3$ and band-insulator Nb:SrTiO$_3$ determined by X-ray photoemission spectroscopy

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1 Introduction
Heterointerfaces of transition metal oxides have attracted considerable interest because of their unusual electronic and/or magnetic properties. One interesting aspect of these heterointerfaces, from the point of view of fundamental studies and device applications is the modulation of ferromagnetism [1] and the appearance of new optical transitions [2] between interface states in superlattices consisting of a “p-type” Mott-insulator LaMnO$_3$(LMO) and n-type semiconductor SrTiO$_3$(STO). For understanding these novel phenomena, it is indispensable to elucidate the band diagram of the interface. In this study, we have investigated the band profile of LMO/Nb-doped STO (Nb:STO) p-n junctions at different donor concentrations using X-ray photoemission spectroscopy.

2 Experiment
Epitaxial LMO films with various thicknesses were grown on 0.05 wt. % and 0.5 wt. % Nb-doped STO substrates by laser molecular beam epitaxy. After thin film growth, samples were transferred to an XPS chamber without air exposure and XPS measurements were performed using a VG-Scienta R3000 analyzer with a monochromatized Al K$_\alpha$ X-ray source ($h\nu = 1486.6$ eV).

3 Results and Discussion
Figure 1 shows Ti 2p core level spectra of Nb:STO covered by a LMO overlayer. The positions of the Ti 2p core levels shift to lower binding energies with increasing LMO overlayer thickness for both junctions, irrespective of the Nb doping concentration. These energy shifts correspond to the built-in potentials formed in Nb:STO due to band bending. Notably, the energy shifts change depending on the donor concentration, being 0.55 ± 0.05 eV for Nb: 0.05 wt. % and 0.25 ± 0.05 eV for Nb: 0.5 wt. %. Based on the p-n junction model of conventional semiconductors, the total built-in potential of a LMO/Nb:STO junction was estimated to be 0.63 eV and the hole density in the LMO film was $6.0 \times 10^{20}$ cm$^{-3}$. These values are consistent with previous results obtained from transport properties [3,4]. The results indicate that the junction properties of a LMO/Nb:STO heterointerface can be accurately described in the framework of the p-n junction model.

Fig. 1 Ti 2p core-level photoemission spectra of LMO/Nb:STO heterointerface. (a) Nb: 0.05 wt. %, (b) Nb: 0.5 wt. %

References

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