Robust Ti$^{4+}$ states in SrTiO$_3$ layers of La$_{0.6}$Sr$_{0.4}$MnO$_3$/SrTiO$_3$/La$_{0.6}$Sr$_{0.4}$MnO$_3$ junctions

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Introduction
Spin tunnel junction based on half-metallic materials has a great potential for future magnetoelectronic applications, such as tunneling magnetoresistance (TMR) devices [1]. Hole doped manganese oxide La$_{0.6}$Sr$_{0.4}$MnO$_3$ (LSMO) is one of the most promising materials for TMR devices owing to their half metallic nature. However, the performance of TMR devices based on the LSMO/SrTiO$_3$(STO)/LSMO tunneling junction, in which STO is used as a tunnel barrier, is far below what is expected from the high spin polarization, suggesting the "dead layer" formation at heterointerfaces between LSMO and STO [2]. In order to investigate an interfacial electronic structure, we have performed Ti 2$p$ core-level photoemission and x-ray absorption spectroscopic (XAS) studies on the insulating barrier STO sandwiched by LSMO layers.

Experimental
The LSMO/STO/LSMO junctions were fabricated in a laser MBE chamber connected to a synchrotron radiation photoemission system at BL-2C of the Photon Factory [3]. A Nd:YAG laser was used for ablation in its frequency-tripled mode ($\lambda$ = 355 nm) at a repetition rate of 1 Hz. During deposition, the substrate temperature was kept at 1050 °C and the oxygen pressure was 1 x 10$^{-4}$ Torr. After cooling down below 100 ºC, the multilayers were transferred into the photoemission chamber under the vacuum of 10$^{-10}$ Torr. The PES spectra were taken with total energy resolution of about 150 meV. The XAS spectra were obtained by measuring the sample drain current.

Results and Discussion
Figure 1 shows the Ti 2$p$ core level spectra of the LSMO/STO/LSMO junction. The elemental selectivity of the techniques enables us to extract the electronic structure (valency) of the STO layer. We have found that Ti 2$p$ core-level spectra clearly show Ti$^{4+}$ states and do not exhibit any indication of Ti$^{3+}$ states in TiO$_2$ layers irrespective of a different kind of adjacent atomic layer with different chemical carrier concentration. This result indicates that the Ti ions in the TiO$_2$ atomic layers preserve their tetravalent states even in the vicinity of the valence-mismatched interface between LSMO and STO, reflecting chemical stability of the Ti$^{4+}$ states.

References

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Fig1: Ti 2p core-level spectra of STO layers with different layer thicknesses for LSMO/STO/LSMO junctions.