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Thickness-dependent electronic structure of $LaNiO_3$ ultrathin films

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Introduction

Immediately after predicting the similarity in electronic structures of $LaNiO_3$(LNO)/$LaAlO_3$(LAO) superlattices to high-T_c cuprate [1], a number of the experimental efforts have been devoted to explore the possible high-T_c superconductivity in the heterostructures based on LNO [2]. The theory predicted the emergence of the two-dimensional electron liquid states in the LNO layer as results of the quantum confinement of Ni 3*d* electrons and the e_g orbital ordering. However, almost all experiments reported that the heterostructures underwent the transition from metal to insulator (MIT) at a critical LNO-layer thickness of 3-5 ML [2,3], strongly implying the intrinsic insulating ground states of the LNO layer with a few ML thicknesses. In order to investigate how the electronic structure changes as a function of layer thickness, we have performed *in-situ* photoemission spectroscopy (PES) on LNO ultrathin films grown onto LAO substrates with varying film thickness.

Experiment

LNO ultrathin films were grown onto the LAO (100) substrates in a laser molecular-beam epitaxy chamber connected to a synchrotron-radiation photoemission system at BL2C. LNO films were deposited at the substrate temperature of 450 ˚C under an oxygen partial pressure of 10^{-3} Torr. The atomically flat surface and chemically abrupt interface were confirmed by atomic force microscope and cross-section transmission electron microscopy, respectively. The PES spectra were recorded at room temperature using an SES 2002 electron energy analyzer with the total energy resolution of 120 meV at the photon energy of 600 eV.

Results and Discussion

Figure 1 shows the *in-situ* PES spectra near the Fermi level (E_F) of digitally-controlled LNO ultrathin films. These spectra exhibit remarkable and systematic changes as a function of the LNO film thickness. The spectra consist of structures located just at E_F and around 1.5 eV, which are assigned to e_g and t_{2g} states, respectively. At a film thickness of thinner than 6 ML, spectral weight at E_F decreases steeply with decreasing film thickness. As a result, a pseudogap seems to be formed at E_F below 4 ML. With a further decrease in the film thickness, the pseudogap finally evolves to an energy gap at E_F, indicating that thickness-dependent MIT occurs at a critical film thickness of 3–5 ML. The observed spectral behavior across the MIT is quite similar to that for bandwidth controlled MIT in RNiO$_3$. These results suggest that dimensional-driven MIT [4] occurs in LNO ultrathin films as a consequence of the reduction of bandwidth due to a decrease in the effective coordination number of constituent ions at the interface and surface.

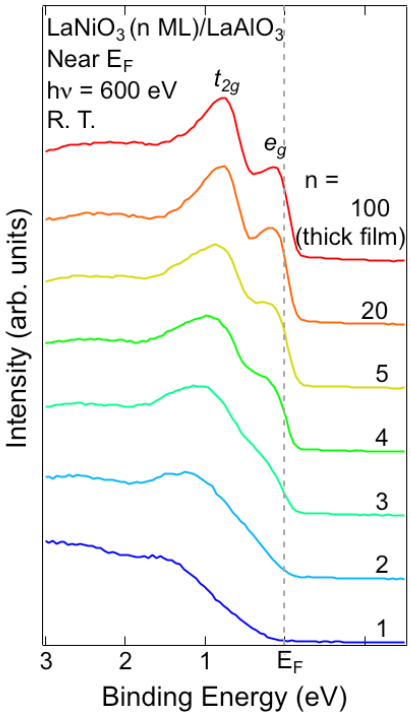

Figure1: *In-situ* PES spectra near E_F of $LaNiO_3$ (n ML)/$LaAlO_3$.

References

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