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Charge distribution and ferromagnetism at the heterointerface between perovskite oxides $LaNiO_3$ and $LaMnO_3$

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Heterointerfaces between perovskite transition metal oxides have attracted much attention because of their novel electronic and/or magnetic properties. Recently, it has been reported that an unusual spin order occurs in a paramagnetic $LaNiO_3$ (LNO) layer in the heterointerface region with a "ferromagnetic" $LaMnO_3$ (LMO) layer, resulting in the appearance of the exchange bias between the two oxides [1]. These exotic magnetic properties may originate from the charge redistribution resulting from the interfacial charge transfer between Ni and Mn ions [2]. Therefore, for understanding the magnetic properties appearing at the heterointerface of LNO/LMO, it is indispensable to elucidate the relationships between the charge redistribution and the interfacial ferromagnetism. In this study, we have investigated the electronic and magnetic states of both the transition-metal ions in the interfacial region by utilizing the elemental selectivity and surface (interface) sensitivity of x-ray absorption spectroscopy (XAS): The changes in valence of both ions caused by the interfacial charge transfer and their spatial distributions are determined by XAS, while the induced magnetization by magnetic circular dichroism (MCD) of XAS.

The XAS measurements on toplayer for LNO/LMO and LMO/LNO bilayers demonstrated the occurrence of the electron transfer from LMO layers to LNO layers ($Ni^{3+} + Mn^{3+} \rightarrow Ni^{2+} + Mn^{4+}$) in the interface region [3]. Thus, to evaluate the spatial distribution of the interfacial charge transfer, we have measured the thickness dependent XAS spectra of *underlayers* for the both bilayers. Judging from the *overlayer* thicknesses with which the spectral change of *underlayers* are saturated, the spatial distributions of transferred charges are significantly different between two layers: 1 ML for the LNO side, while 3–4 ML for the LMO side [3]. Meanwhile, as shown in Fig. 1, the Ni-$L_{2,3}$ X-ray MCD (XMCD) spectra of LMO/LNO/LMO sandwiched structures have revealed that net magnetization is induced in the Ni^{2+} ions at a 1-ML LNO layer adjacent to the interface owing to the interfacial charge transfer. As for the counterpart Mn ions, the magnetic moment increased from that of LMO bulk within the 3–4 ML LMO layers from the interface where the transferred holes were distributed. Furthermore, both magnetic moments were ferromagnetically coupled to each other. These results suggest that the stabilization of ferromagnetism in LMO layers due to the interfacial charge transfer and the resultant ferromagnetic coupling between Ni and Mn spins are keys to understanding the induced net magnetization in Ni ions at the interface.

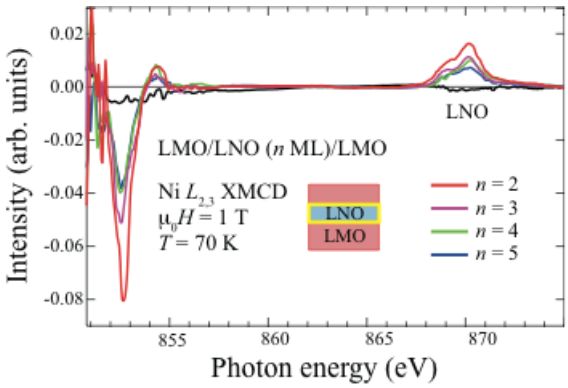

Fig. 1. Ni-$L_{2,3}$ XMCD spectra of the LMO (5 ML)/LNO (n ML)/LMO (20 ML) sandwiched structures (n = 2–5).

1) M. Gibert *et al*., *Nat. Mater.* **11**, 195 (2012). 2) T. Koida *et al*., *Phys. Rev. B* **66**, 144418 (2002).
3) M. Kitamura *et al*., *Appl. Phys. Lett.* **108**, 111603 (2016).