

Composition dependence of electronic states and valencies in epitaxial $\text{LaNi}_{1-x}\text{Mn}_x\text{O}_3$ thin films studied by X-ray absorption spectroscopy

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Introduction

Spintronics has attracted much attention as a new technology that takes advantage of not only electric charge but also spin. $\text{La}_2\text{NiMnO}_6$ is a ferromagnetic semiconductor that has a potential of applying to spintronics devices because of its ferromagnetic transition temperature ($T_c \sim 280$ K). The ferromagnetism of $\text{LaNi}_{0.5}\text{Mn}_{0.5}\text{O}_3$ is explained by the mechanism due to a superexchange interaction in Ni-O-Mn, which is predicted theoretically by Kanamori-Goodenough (G-K) rules. However, electronic states of transition metals responsible for the ferromagnetic interaction have not been elucidated yet. G-K rules predict both $\text{Ni}^{2+}(d^8)\text{-O-Mn}^{4+}(d^3)$ [1] and $\text{Ni}^{3+}(d^7)\text{-O-Mn}^{3+}(d^4)$ [2] interactions to exhibit a ferromagnetic behavior. In this study, X-ray absorption spectroscopy (XAS) of $\text{LaNiO}_3\text{-LaMnO}_3$ composition spread films was carried out to evaluate the valence states of transition metal ions for studying the origin of ferromagnetism in $\text{LaNi}_{0.5}\text{Mn}_{0.5}\text{O}_3$.

Experimental

Epitaxial $\text{LaNiO}_3\text{-LaMnO}_3$ composition spread films were fabricated on $\text{LaAlO}_3(100)$ substrates using a pulsed laser deposition method. During deposition, the substrate temperature was kept at 600 °C at an oxygen pressure of 100 mTorr. Composition and structures of the films were characterized by X-ray fluorescence (XRF) and X-ray diffraction (XRD), respectively. XAS spectra were obtained by measuring the sample drain current at an undulator BL-2C beamline.

Results and discussion

Figure 1 shows Ni $2p \rightarrow 3d$ absorption spectra (a) and Mn $2p \rightarrow 3d$ absorption spectra (b) at room temperature. With increasing the incorporated Mn into $\text{LaNi}^{3+}\text{O}_3$, Ni $2p_{3/2}$ single peak is becoming split into double peaks where the lower energy peak is emerging, as shown in Fig. 1 (a). Mederde *et al.* reported that Ni $2p_{3/2}$ spectra of $\text{NdNi}^{3+}\text{O}_3$ and $\text{PrNi}^{3+}\text{O}_3$ are quite different from that of Ni^{2+}O [3]. By comparing our Ni $2p_{3/2}$ XAS spectra with the reported spectra, it is indicated that the valency of Ni varies from Ni^{3+} to Ni^{2+} as a result of Mn substitution in

$\text{LaNi}^{3+}\text{O}_3$. Mn $2p_{3/2}$ spectra also show changes in shape with the substitution of Ni by Mn, as shown in Fig. 1 (b). This suggests that the replacement of Ni by Mn increases the valency of Mn from Mn^{3+} to Mn^{4+} , which is consistent with $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ XAS spectra obtained by Abbate *et al.* [4]. Thus, the valency changes from Ni^{3+} to Ni^{2+} , and from Mn^{3+} to Mn^{4+} due to the charge transfer from Mn to Ni were clearly observed. This charge transfer results in a ferromagnetic semiconductor $\text{LaNi}_{0.5}\text{Mn}_{0.5}\text{O}_3$ consisting of mainly Ni^{2+} and Mn^{4+} . Therefore, it is suggested that a superexchange interaction between Ni^{2+} and Mn^{4+} via an oxygen ion rather than Ni^{3+} and Mn^{3+} is the origin of ferromagnetism in $\text{LaNi}_{0.5}\text{Mn}_{0.5}\text{O}_3$.

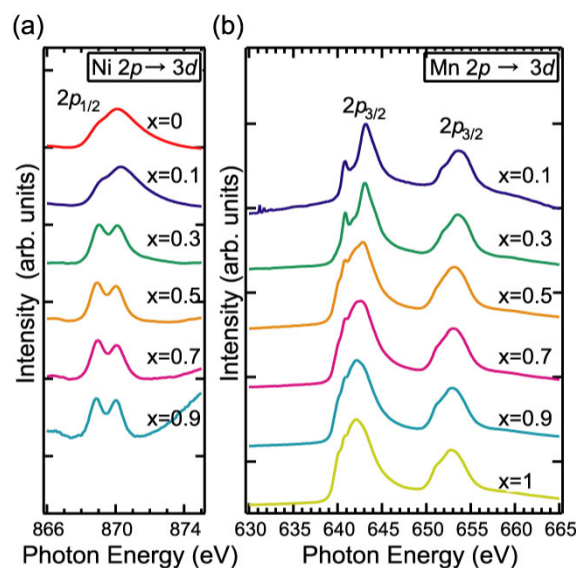


Fig. 1: XAS spectra of $\text{LaNi}_{1-x}\text{Mn}_x\text{O}_3$: (a) Ni $2p \rightarrow 3d$, (b) Mn $2p \rightarrow 3d$.

References

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