Surface observation of $LaNiO_3$/MgO (100) structure

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In our previous papers [1, 2], highly-oriented and polycrystalline $LaNiO_3$ (LNO) thin films were successfully prepared by using chemical solution deposition (CSD) process with a mixed solution of La- and Ni-naphthenates as precursors, and the crystallinity and resistivity of the LNO thin films were fully discussed.

The surface morphology, including surface roughness, of a thin film often determines the electrical or the optical properties that are crucial to the performance of a device. In an effort to understand and control film growth, it is important to characterize the surface during and after deposition. In the case of conductive thin films used as the bottom electrode, a homogeneous surface corresponding to a smooth and dense interface between electrode and upper film are required for electrical applications [3, 4].

In this work, we present an atomic force microscope (AFM) study on the LNO films on (100) MgO substrate, with particular interest being paid to the influence of substrate on the surface morphology and roughness.

Briefly, the fabrication method for the LNO thin films is described in detail in our previous work [1]. The starting precursor solution was prepared by mixing the constituent metal naphthenats of La and Ni in toluene to achieve an appropriate viscosity for deposition of smooth films, the preheating condition was 500°C for 10 min in air, and final annealing condition was 750°C for 30 min in air. Preheating is a process for pyrolytic conversion of organic acid salts into carbonate or composite metal oxide, and the final annealing is the crystallization process for the LNO phase.

All AFM measurements described here were performed with a NanoScope Multimode^{TM} scanning probe microscope (SPM) from Digital Instruments, which was operated with the tapping mode (non-contact) imaging technique to prevent damage to the thin films and to provide optimal image and data quality. The resonant frequency of the silicon probe was ~260 kHz, and the scan rate and tip velocity were 1.0 Hz and 20.0 μm s^{-1}, respectively. The root mean square (RMS) values and the power spectral density (PSD) curves used throughout this work were calculated from selected AFM scans with the NanoScope off-line analysis software.

Fig. 1 shows X-ray diffraction scans of LNO\MgO. The film showed an oriented (100) peak as well as a misoriented (111) reflection.

A graphical impression of the surface microstructure is obtained by directly viewing the 3-dimensional AFM images. Fig. 2 shows the AFM image and area roughness of the surface of LNO/MgO. The surface is relatively smooth, i.e., root mean square (RMS) roughness = 10.966 nm, although abnormal growth of some grains was identified.

Determination of PSD functions of the coated samples conveys more detailed information on the contribution of surface roughness to the microphotography. Fig. 3 shows the PSD curve of LNO film. The PSD curve is represented by the "protrusion" at spatial frequencies around 1 μm^{-1}, indicating the presence of a number of grains with sizes corresponding to the frequencies around 1 μm^{-1}. Consequently, the frequency range where the PSD curve is enhanced by LNO thin

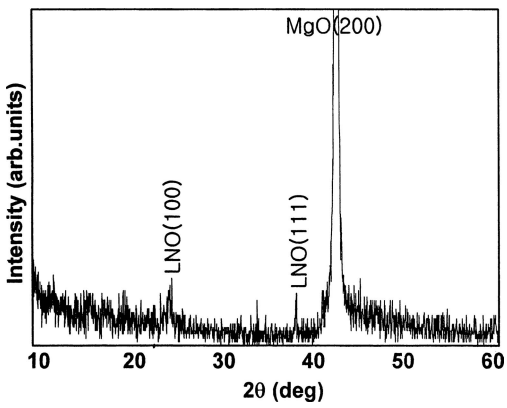

Figure 1

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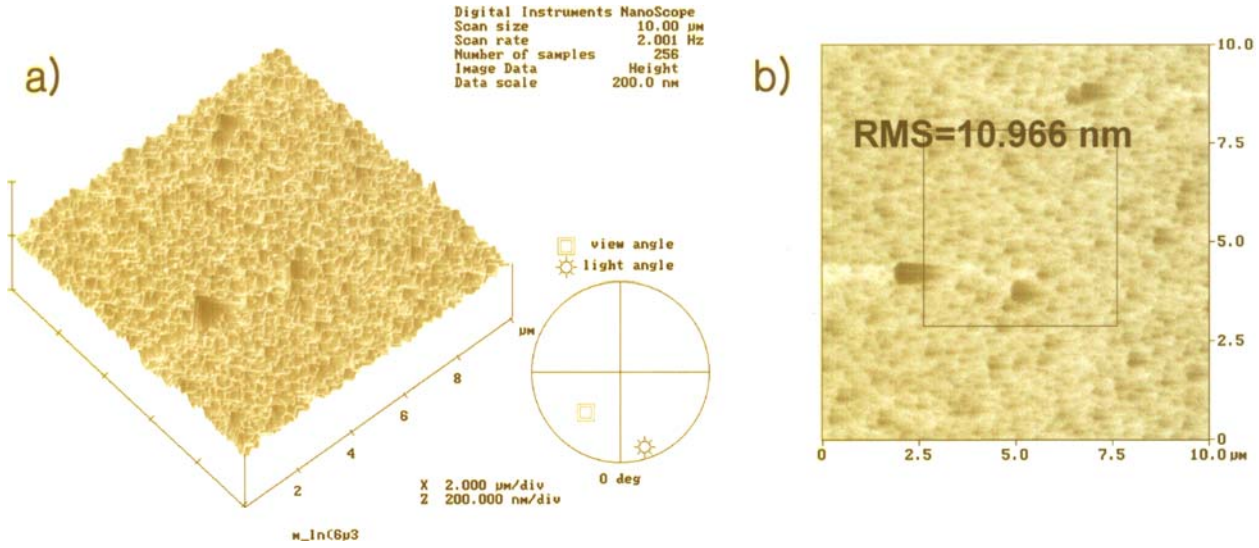

Figure 2

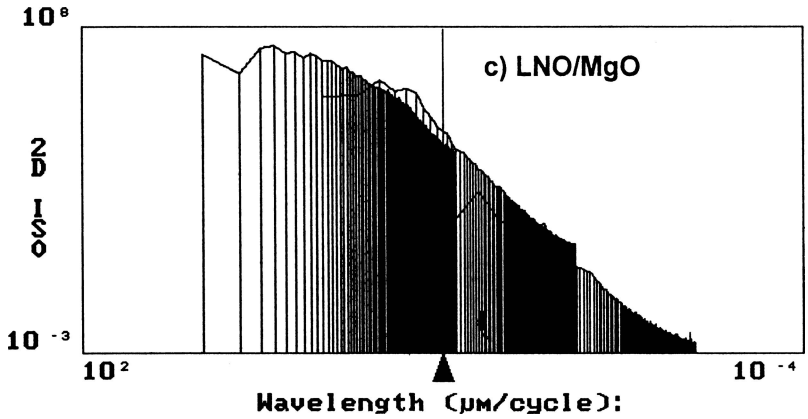

Figure 3

film on MgO shifts to lower frequencies (i.e., to roughness components of larger lateral extension), which corresponds to the lateral growth of grains, as displayed in the AFM images. In particular, the steep rise of the PSD curve of LNO on MgO at lower spatial frequencies may result from some high grains. From this PSD curve, knowledge is gained about the roughness contributions from the particular spatial wavelengths.

LNO has rhombohedral symmetry with lattice parameter of $a = 0.546$ nm. Pseudocubic "a" and thermal linear expansion coefficient of this oxide are 0.384 nm and $\beta = 8.2 \times 10^{-6}$, and they match well those of $SrTiO_3$(STO) ($a = 0.3905$ nm, $\alpha = 10.3 \times 10^{-6}$) and $LaA1O_3$(LAO) ($a = 0.379$ nm, $\alpha = 9.2 \times 10^{-6}$). On comparing LNO thin film on MgO ($a = 0.4216$ nm) with those on STO and LAO, some abnormal grain growth of LNO/MgO was reasonable because of the relatively larger lattice misfit value. Furthermore, we assumed that a large difference of thermal expansion coefficient between LNO and MgO ($\alpha = 12.8 \times 10^{-6}$) was one factor of increasing surface roughness, while LNO on STO and LAO having a similar value exhibited a high-quality epitaxy and surface smoothness [1, 5].

In summary, we investigated surface morphology of LNO thin film on MgO (100) substrate by using an atomic force microscope. Chemical solution derived LNO was prepared by using a metal naphthenate precursor. The LNO/MgO showed some abnormal grain growth and misoriented phases. A relatively rough surface structure was obtained in consequence of large lattice-misfit value and difference of thermal expansion coefficient between LNO and MgO.

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