Structural Studies of Sputtered $La_{0.7}Sr_{0.3}MnO_3/LaNiO_3$ Superlattices

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Magnetic oxide superlattice films have caused much intensive research for their technological use in magnetic recording media and sensors. Among various oxide materials of the perovskite type, $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and $LaNiO_3$ (LNO) have attracted much attention because $La_{0.7}Sr_{0.3}MnO_3$ is a ferromagnetic metallic phase and $LaNiO_3$ is a paramagnetic metallic phase near 300K; $LaNiO_3$ can serve not only as interlayer spacer but also in buffer layers that assist $La_{0.7}Sr_{0.3}MnO_3$ to form epitaxial superlattice films. A small lattice mismatching between manganites and nickelates, together with their chemical stability, make the fabrication of high quality epitaxial heterostructures consisting of alternating layers of $La_{0.7}Sr_{0.3}MnO_3$ and $LaNiO_3$ possible. Nowadays, many researches that discuss strain correlated magnetic properties mostly focus on thickness dependence. However, it is hard to differentiate the variation of magnetic properties are really caused by lattice distortion or increasing thickness. Because we know that the magnetic properties would approach the bulk value as film thickness raising up. In order to discriminate the magnetic properties of thickness from strain dependence, we fabricated LSMO/LNO superlattices with varied deposition temperatures to observe the changes of the crystalline of the films based on the same architecture.

The LSMO/LNO superlattice was grown on a single-crystal $SrTiO_3$ (STO) (001) substrate with a triple-gun rf magnetron sputtering system The sputtering was performed at a power density 1.5 W cm^{-2} for both LSMO and LNO with a highly purified gas (O_2 25 % + Ar 75 %) at a working pressure 1.33 Pa. We adopted a symmetric (t_{LSMO}/t_{LNO} = 2.5 nm/2.5 nm) sublayer structures and the superlattices contain 10 periods of LSMO/LNO bilayers. The total thickness of the LSMO/LNO suuperlattices films were fixed at ~ 50nm. The x-ray scattering experiments were carried out on wiggler beamline BL17B1 at the National Synchrotron Radiation Research Center (NSRRC), Taiwan.

Figure 1 shows crystal-truncation-rod (CTR) spectra along the [0 0 L] direction of the LSMO/LNO superlattice films with varied substrate temperatures. The intense and sharp feature centered at L = 2 is the STO (002) Bragg reflection from the substrate, as shown in Fig. 1. The clearly discernible main feature and satellite features on both sides of the substrate indicate the high quality of the LSMO/LNO artificial superlattice structure have been formed on a STO substrate. The higher is the deposition temperature, the more clearly present are the satellite peaks. The distribution of in-plane x-ray intensity of radial scans from superlattice films with varied substrate temperatures is shown in Fig. 2.

The position of the out-of-plane (002) main peak for all superlattice films is larger than the mean value of the superlattice film and away from the STO substrate Bragg peak with increasing deposition temperature. This condition indicates that the superlattice films become subject to increased compress stress along c-axis as increasing the deposition temperature. On the contrary, the position of the in-plane main peak for all superlattice films is smaller than the mean value of the superlattice and approaches the STO substrate Bragg peak with increasing the deposition temperature. It reveals that the superlattice films become subject to increased tensile stress parallel to the surface plane as increasing the deposition temperature. Above results clearly show the superalttices would get more compress stress along the c-axis and more tensile stress parallel to the surface plane as increasing the deposition temperature. Therefore, the superlattices films deposited at a higher temperature have a more greatly strained state than for the films deposited at a lower temperature.

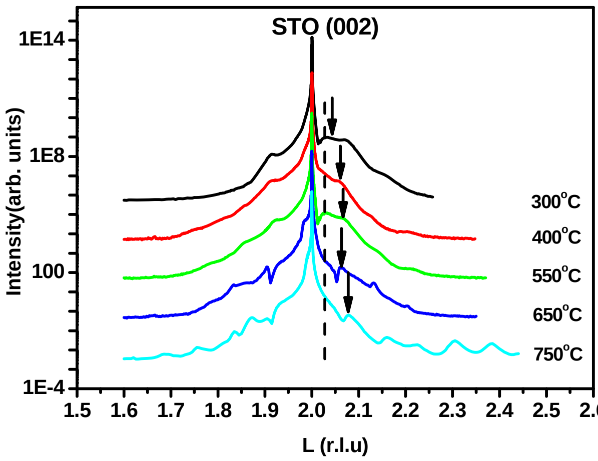

Figure 1. Intensity distribution of a (002) CTR spectrum of LSMO/LNO superlattice films with varied thickness of LNO spacer layer. An arrow marks the position of the superlattice main peak.

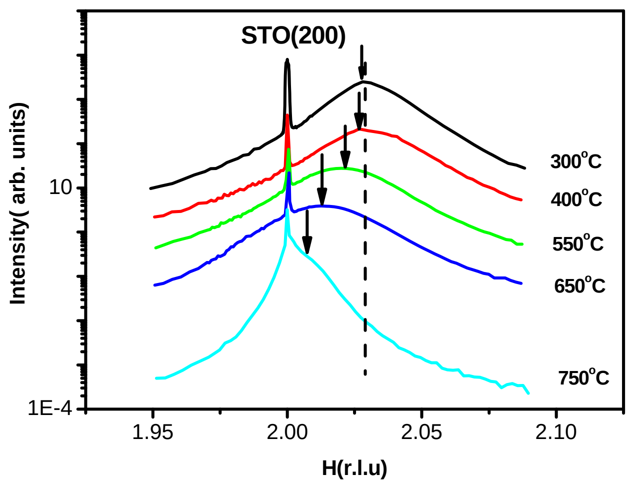

Figure 2. X-ray intensity of a set of radial scans along the (200) in-plane Bragg peak of LSMO/LNO superlattice films with varied substrate temperatures.