Q-1

Strain induced magnetic stripe domains in $La_{0.7}Sr_{0.3}MnO_3$ thin films

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I. Introduction

Recently doped perovskite manganites have renewed interest because they exhibit a variety of unique magnetic and electronic behaviors such as colossal magnetoresistance (CMR), percolative phase separation, spin/charge/orbital ordering, and so on. For this reason, fabrication of thin films with the best surface morphology and controlling their magneto transport properties is essential for making magneto-resistive devices. It has been known that the magnetic and transport properties of the manganite thin films are very sensitive to not only microstructure but also lattice strain induced by the underlying substrate. In addition, the local magnetic domain structure also plays an important role in determining their properties.

II. Experimental method

The LSMO films were grown on (100) LAO , (100) STO, and (110) NGO substrates by pulsed laser deposition in an oxygen partial pressure of 450 mTorr, where the substrates were maintained at a temperature of 750 ^{0}C. The thickness of the films studied in the present study was about 110 nm . The crystallinity and orientation of the films was characterized by x-ray diffraction. The magnetic properties were determined with a superconducting quantum interference device (SQUID) magnetometer. Atomic force microscopy (AFM) and MFM images were taken at room temperature using a Park auto-probe CP scanning force microscope.

III. Results and discussion

The *c*-axis lattice constants of the LSMO films on LAO, NGO, and STO substrates calculated from the x-ray data are 3.930 Å, 3.906 Å, and 3.855 Å, respectively. This suggests that the LSMO film experiences either compressive or tensile stress due to lattice mismatch between the LSMO film and the underlying substrate. For the LSMO film on LAO, the bi-axial compressive stress is anticipated because both *a* and *b* axes are mismatched. Whereas, LSMO on NGO undergoes a uni-axial compressive strain in which only the *a*-axis is significantly different. However, the LSMO layer on STO that has larger lattice size is under a bi-axial tensile stress.

In order to examine the surface morphology, we have performed AFM studies. AFM images of the three films do not show any noticeable difference although the size and shape of grains slightly depends on the underlying substrate. LSMO films on NGO and STO appear to consist of grains with rounded-shapes, while grains with elongated island-like shapes are dominant in the film on LAO. However, the root mean square roughness (R_{rms}) and the maximum peak to valley

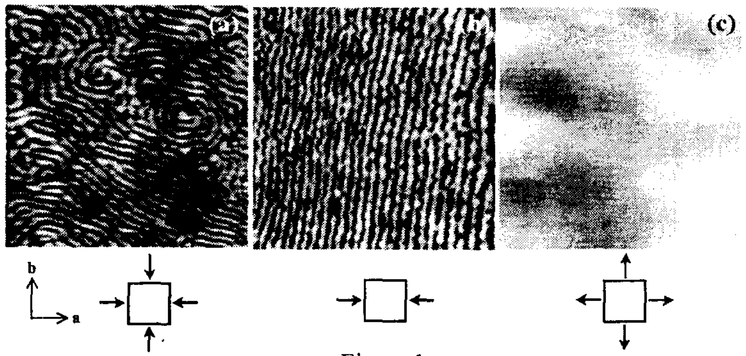

Figure 1

roughness (R_{p-v}) values of the three films are almost identical, which are in the range of 7.5 (± 1.0) Å and 190 (± 5) Å, respectively. These values suggest that the surface morphologies are very smooth and in turn their MFM images are primarily due to the magnetic interaction between the film and the magnetic particle on the tip. The temperature dependence of magnetization M(T) curves for LSMO films on LAO and STO clearly reveal that they have a ferromagnetic transition near 350 K.

Figure 1 shows three MFM images of the LSMO films taken in zero field at room temperature, where scan size is typically 4 μm × 4 μm. Since there is no direct correlation between the surface morphology and the magnetic domain pattern, the observed bright and dark contrast images are representative of domains with different magnetic orientation. The MFM image on STO shows feather-like magnetic patterns with negligible contrast, which is typical of a film with an in-plane magnetization.[1] On the other hand, maze-like stripe domains, which are consistent with a perpendicular anisotropy, are observed in the LSMO film on LAO.[2] This stripe domain pattern is indicative of a film with an out-of-plane magnetization. The MFM image of the film on NGO exhibits a remarkable feature in that magnetic domains have highly ordered stripe patterns. From cross-sectional profiles, the mean periodicity of the domains is about 120 nm, which is twice the domain width. It is worthy to mention that the stripe are typically well-observed in films with thickness of about 120 nm, implying that the domain images are dependent on the film thickness.

IV. Conclusion

In summary, our results clearly show that magnetic domain shapes are dependent on the strain induced by the substrate. Another important finding is that movement of domains is sensitive to the field direction. The ability to control these magnetic domains opens new opportunities to make new field sensitive device by the fine-tuning of the lattice mismatch between the film and the substrate with a piezoelectric substrate or the direction of magnetic field.

V. References

[1] C. Kwon et al. J. Magn. Magn. Mater. **172**, 403 (1997).

[2] Y. Wu et al. Appl. Phys. Lett. **75**, 2295 (1999).