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Low-Temperature MFM Studies of CMR Manganites *

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We have performed low-temperature Magnetic Force Microscopy (MFM) studies of colossal magneto-resistive (CMR) $(La_{0.67}Ca_{0.33})MnO_3$ films prepared by physical vapor codeposition (PVCD). The samples exhibit sharp metal-insulator transitions at T_c =265 K, and 120 nm grain structures. MFM studies performed down to T = 77 K showed irregularly-shaped magnetic features at temperatures below T_c. Characteristic magnetic domain sizes were 1–2 μm, which exceeds the grain size for these films, implying coherence across grain boundaries in this system.

1. INTRODUCTION

Giant magnetoresistance is observed in many systems [1], and is associated with the occurrence of magnetic disorder in conducting systems. Colossal magnetoresistance (CMR) is the unusually large effect observed in rare-earth manganites, where the disorder is believed to be spin disorder near a ferromagnetic transition. While the associated metal-insulator transition has been explained in terms of double-exchange [2], there is evidence for the role of local inhomogeneities [3], in the form of magnetic polarons or phase separation.

Magnetic force microscopy (MFM) provides an effective probe for inhomogeneous magnetism. We report MFM studies of films showing how the magnetic domains interact with the sample structure.

2. EXPERIMENTAL DETAILS

Our $La_{0.67}Ca_{0.33}MnO_3$ films were grown on $LaAlO_3$ substrates by physical vapor codeposition (PVCD) methods described elsewhere [4]. After O_2 annealing, the films exhibited a sharp resistivity upturn at 265 K (the maximum slope) which defines T_c. MR ratios near 80 % ($[\rho_0-\rho_H]/\rho_0$) were observed in 5.0 T for $x = 0.33$ films. WDS scans showed the compositions of these films to be uniform.

AFM and MFM images were obtained using a ThermoMicroscopes system with a homemade scan head, and Piezolevers which we coated with Co for MFM. We used a cold-finger cryostat to cool the sample. Contact and non-contact scans were interleaved; with near-surface tip location, contact scans provide the sample topology, while non-contact scans obtained by oscillating the tip tens of nm from the surface, provide predominantly magnetic information.

3. RESULTS AND DISCUSSION

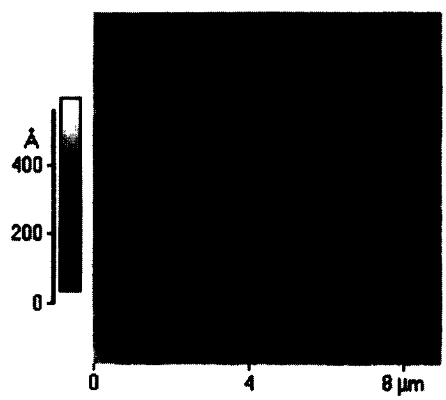

Figure 1. Contact image taken at 300 K.

A room-temperature topographic image is shown in Figure 1. Topographic images at all temperatures were similar to this image. The typical lateral feature size is 400 nm. Analysis of powder x ray spectra for this sample indicated a crystal grain size of approximately 120 nm.

Room-temperature non-contact images exhibit no magnetic information, showing only topography similar to Figure 1. At low temperatures, 1–2 μm magnetic features dominate. Figure 2 is a 210 K image,

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while Figure 3 is a 229 K image showing the domain structure more clearly. Figure 4, taken at 239 K, shows structures with smaller amplitude. Domains become less distinct near T_c, disappearing between 255 and 260 K. The T_c from resistivity of the same film was 265 K, so the observed behavior is quite consistent with that of ferromagnetic domains.

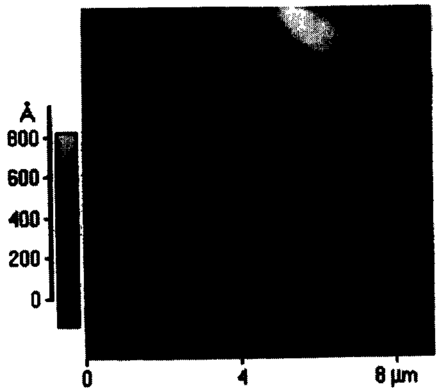

Figure 2. MFM image taken at 210 K.

Comparing to previous work, we have not observed the "maze"-type domain patterns seen in [5]. By contrast, our domains are quite similar in size and shape to those observed on evaporated films in [6]. Although in [6] topographic structures were associated with a competing phase, AFM images and WDS scans in our films indicate phase uniformity, showing that crystalline grains are the main topographic features.

Clearly the magnetic domains encompass multiple grains within these films. This is reminiscent of the magnetic correlation observed between particles in a granular GMR system [7]. For magnetic coherence to persist across crystal boundaries within the framework of the double exchange mechanism [2] requires hopping of Mn d-holes across the boundaries, which in turn requires that the local electronic structure not be strongly perturbed by these boundaries.

Currently we are studying more highly oriented films prepared by pulsed laser deposition methods.

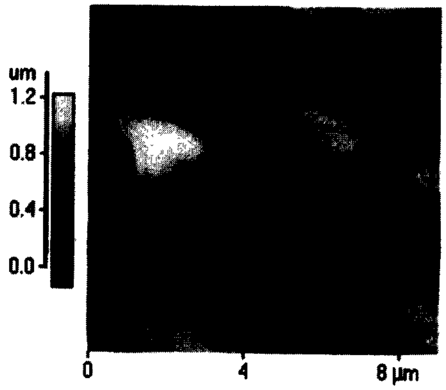

Figure 3. MFM image taken at 229 K.

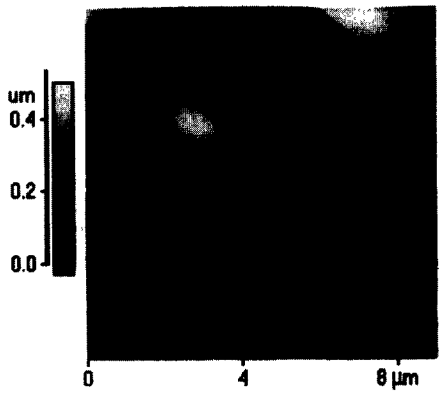

Figure 4. MFM image taken at 239 K.

REFERENCES

1. J M D Coey, in Aspects of Modern Magnetism, F C Pu, Y J Wang, and C H Shang (eds.), World Scientific, Singapore, 1996, p. 2.
2. C Zener, Phys. Rev. 82 (1951) 403.
3. A J Millis, B I Shraiman, and R Mueller, Phys. Rev. Lett. 77 (1996) 175; M Uehara, S Mori, C H Chen, and S-W Cheong, Nature 399 (1999) 560.
4. K D D Rathnayaka, A Parisiris, C Andrews, J Chepin, A K Bhatnagar, A C Du Mar, and D G Naugle, Mater. Lett. 37 (1998) 21.
5. C Kwon, M C Robson, K-C Kim, J Y Gu, S E Lofland, S M Bhagat, Z Trajanovic, M Rajeswari, T Venkatesan, A R Kratz, R D Gomez and R Ramesh, J. Magn. Mag. Mater. 172 (1997) 229.
6. Q Lu, C-C Chen, and A de Lozanne, Science 276 (1997) 2006; C-C Chen, Q Lu, and A de Lozanne, Appl. Phys. A 66 (1998) S1181.
7. Y J Chen, W Y Cheung, I H Wilson, N Ke, S P Wong, J B Xu, H Sang, and G Ni, Appl. Phys. Lett. 72 (1998) 2472.