In-plane Field Induced Structural Change of Magnetic Domains in Layered Manganite $La_{1.36}Sr_{1.64}Mn_2O_7$

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Abstract

We present a study of structural change of the magnetic domains in $La_{1.36}Sr_{1.64}Mn_2O_7$ using magneto-optical effect of a garnet film mounted on the *ab*-plane of a crystal. The maze domain formed below 65 K changes into the stripe domain elongated along field direction by applying in-plane field. Under an offset field perpendicular to the plane, however, the domain pattern changes into bubbles. These domain patterns are stable even after removing the field. The in-plane field needed for such structural change becomes small at higher temperatures. These changes are similar to those observed in bubble garnet films.

Key words: layered manganite; magnetic domain; CMR

1. Introduction

Bilayer manganites $La_{1+2x}Sr_{2-2x}Mn_2O_7$ have rich phase diagram [1]. There are some reports about magnetic domain structures near x=0.3, which have uniaxal anisotropy in some temperature regions. In x=0.3 compound, Fukumura and co-workers reported the existence of "spontaneous" bubble domain by using scanning Hall probe microscope [2]. More recently, Welp and co-workers observed maze domain in x=0.32 compound which is common in the ferromagnets with uniaxial anisotropy [3]. However, there are few reports focused on external field effects on these magnetic domains structures. In manganites, it is well known that magnetic properties are strongly correlated with transport properties. So if one can control the magnetic domain structure, it may also be possible to control transport properties. Here we present a study of structual change of the magnetic domain in $La_{1.36}Sr_{1.64}Mn_2O_7$ mainly caused by in-plane field with using magneto-optical effect (Faraday effect) of a garnet film mounted on the *ab*-plane of a crystal.

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2. Experiment

Single crystal of $La_{1.36}Sr_{1.64}Mn_2O_7$ was melt grown in 100 % O_2 atmosphere by using floating zone method. Samples were cleaved from the resulting boule. We used the cleaved surfaces for magneto-optical (MO) observations. In-plane field (H_{ab}) and field along *c*-axis (H_{bias}) were applied to the samples by using electromagnets. Garnet indicator film magnetized along in-plane direction was mounted on the *ab*-plane of the crystal. MO images were taken by cooled charge-coupled device (CCD) attached to the polarizing microscope in the cross nicol configuration. Note that all images observed here were on cleaved surfaces, and hence, free from strain caused by polishing process.

3. Results and discussion

Figure 1 shows temperature dependence of magnetization in the field of 100 Oe along the *c*-axis and in-plane direction. No hysteresis is observed in cooling and warming processes. Ferromagnetic transition temperature in this sample is near 120 K. At lower tem-

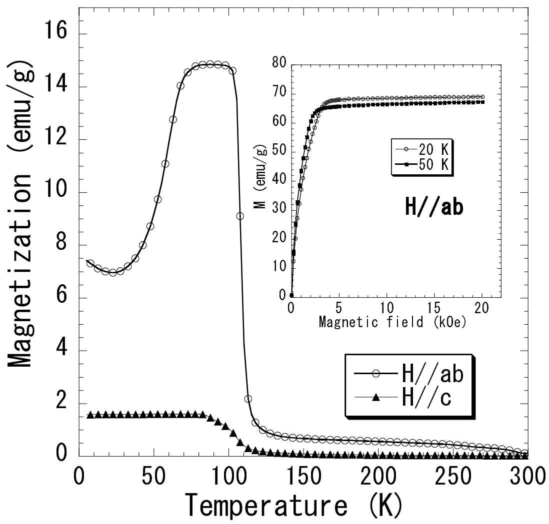

Fig. 1. Temperature dependence of magnetization of $La_{1.36}Sr_{1.64}Mn_2O_7$ along *ab*-plane direction and *c*-axis at 100 Oe. Inset shows applied field dependence of magnetization along in-plane direction up to 20 kOe at 20 K and 50 K.

peratures, magnetization along *c*-axis shows almost constant value, although in-plane magnetization is strongly suppressed. This difference corresponds to the change of easy axis [3]. The first and the second order anisotropy constant K_1 and K_2 calculated from M-H curves along hard axis (*ab*-plane), taking into acount of Zeeman energy and demagnetization factor [3], are $K_1 = 8.4 \times 10^5$ erg/cm^3, $K_2 = 2.3 \times 10^5$ erg/cm^3 at 20 K, and $K_1 = 1.0 \times 10^5$ erg/cm^3, $K_2 = 1.6 \times 10^5$ erg/cm^3 at 50 K respectively.

In MO measurements, the maze domain is observed below 65 K in the zero field cooling process. Fig. 2 (a) shows maze domain observed at 20 K. The thickness of the crystal here is 105 μm. To investigate field-induced effect on this pattern, we apply H_{ab} on it and take an image in the remanent state after removing the H_{ab}. In case that H_{ab} is smaller than 2700 Oe, we observe maze domains elongated along the field direction. Futher increase of H_{ab} causes change into stripe domains as shown in Fig. 2(b). Changes in domain structure also depends on field parallel to the *c*-axis. Fig. 2 (c) and 2 (d) are images taken under bias field H_{bias}=500 Oe parallel to the *c*-axis. At low in-plane field, maze domains are elongated along the field direction (Fig. 2 (c)), which are almost the same as those observed in the former process. After applying higher in-plane field, however, remanent state becomes bubble-like pattern (Fig. 2 (d)). the threshold H_{ab} is again about 2700 Oe. With increasing temperature up to 50 K, the threshold field decreases to 1800 Oe. Such a change is consistent with the decrese of uniaxial anisotropy. Remanent states observed here are quite different from the initial maze domain, though hysteresis in M-H curve is

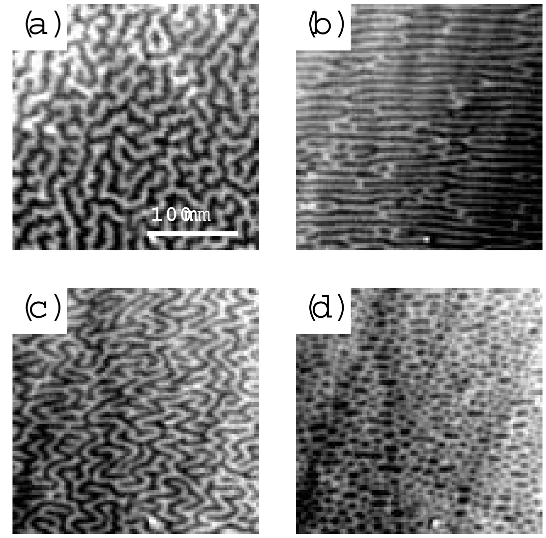

Fig. 2. MO images of (a) state after zero field cool process (b) remanent state after applying in-plane field H_{ab}=2750 Oe (c) remanent state after applying in-plane field H_{ab}=1000 Oe under an offset field H_{bias}=500 Oe perpendicular to *ab*-plane (d) remanent state after applying in-plane field H_{ab}=2750 Oe under an offset field H_{bias}=500 Oe perpendicular to *ab*-plane. All images are taken in the presence of field along H_{pic}=500 Oe for better contrast which is sufficiently small so as not to change the domain structure.

hardly seen. The remanent bubble state here is different from ordinary bubble, because the latter needs bias field perpendicular to the plane for its existence; bubbles observed here are stable even after removing the field, or applying inverse bias field up to 500 Oe. Relaxation to the initial maze domain is not observed in the time scale of a few hours. These structural changes of magnetic domains are similar to those observed in bubble garnet films [4].

In summary, we present a study of in-plane field induced structural change of magnetic domains in $La_{1.36}Sr_{1.64}Mn_2O_7$. The maze domain formed below 65 K changes into the stripe domain by in-plane field. Under an offset field perpendicular to the plane, the domain pattern becomes bubble-like, which is stable even in the remanent state.

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