# Huge Anisotropic Magnetoresistance In Epitaxial $Sm_{0.53}Sr_{0.47}MnO_3$ Thin Films

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**Abstract.** In the present work we have studied the variation of LFMR as a function of the angle (θ) between the applied magnetic field and the plane of the film. DC magnetron sputtering was used for film preparation on LSAT single crystal substrates from $Sm_{0.55}Sr_{0.45}MnO_3$ targets synthesized by the solid state reaction route. X-ray diffraction confirmed the epitaxial nature of these films. These films have simultaneous ferromagnetic and metal insulator transition at ~91K. These films exhibit enhanced low field colossal magnetoresistance ~99% at 3.6 kOe at 80K. Huge anisotropy is observed in the MR, which decreases from ~80% to 6% as θ increases from 0 to 90°. The evolution of the resistance as a function of time and the magnetic field at a constant temperature (T ≈77K) has also been studied.

**Keywords:** $Sm_{0.53}Sr_{0.47}MnO_3$, thin film, anisotropic magnetoresistance.
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## INTRODUCTION

$Sm_{1-x}Sr_xMnO_3$ is a prototypical manganite possessing intrinsic phase instabilities (it is very close to charge/orbital order instability) and multicritical points.[1-3] This low bandwidth (BW) compound shows different types of ground states such as (i) ferromagnetic metal (FMM) at $0.3<x\leq0.52$ (ii) antiferromagnetic insulator (AFMI) for $x>0.52$ and (iii) for $0.4<x\leq0.6$, the charge ordering (CO) occurs with the ordering temperature ($T_{CO}$) increasing from ~140K to 250K as x increases in the above range.[1-3] The competition between the FM, CO/OO, and AFM states becomes dominant near half doping ($x$=0.5), and tricritical peculiarities are observed in the $x$-dependent electronic phase diagram making $Sm_{1-x}Sr_xMnO_3$ an interesting candidate to study phase competition and related phenomena.[1-3] Extensive investigations have been reported on $Sm_{1-x}Sr_xMnO_3$ in poly- and single-crystalline bulk forms. Unfortunately, thin films of this compound, either polycrystalline or epitaxial have not been studied in detail because of difficulty in synthesizing the good quality thin films.[4]

The anisotropic magneto resistance (AMR) in manganites caused by the dependence of resistivity on the angle (θ) between the applied magnetic field (H) and the direction of current (I) is an important property to study.[5] In thin films the reduced dimensionality leads to increases in the easy-axis magnetic anisotropy and a decrease in electrostatic screening. In manganites both strain and magneto-crystalline anisotropy is reasoned for the occurrence of AMR near $T_{IM}$ but detailed explanation for this is still debatable. Apart from the strain and hence the film thickness other factors such the structural defects, spin disorder, nature of the magnetic ground state, phase coexistence, etc. are also expected to play a crucial role. The occurrence and nature of the low field AMR in low bandwidth manganites with strong phase competition such as $Sm_{1-x}Sr_xMnO_3$ has not been given much attention.

## EXPERIMENTAL DETAILS

Thin films with thicknesses of ~200 nm were deposited by on-axis dc magnetron sputtering of a stoichiometric target on the single-crystal LSAT (001) substrates maintained at 800°C at a dynamic pressure of 200 mtorr of Ar (80%)+$O_2$ (20%). The films were then annealed in flowing oxygen at 900°C. Structure and microstructure were characterized by powder X-ray diffraction (XRD, X'Pert PRO PANalytical, Cu K$\alpha$ radiation). Temperature and magnetic field dependent magnetization and resistivity were measured by using a commercial SQUID magnetometer (MPMS-XL/Quantum Design) and PPMS (Quantum Design) respectively.

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## RESULTS AND DISCUSSION

EDAX analysis revealed a small deviation of the film cationic stoichiometry that of the target used and the Sm: Sr ratio was found to be 0.53:0.47. The XRD data shows that the out of plane lattice parameter of the $Sm_{0.53}Sr_{0.47}MnO_3$ (SSMO) film coincide with that of the LSAT, which is 3.868 Å. The occurrence of only (00ℓ) diffraction maxima confirms the oriented growth in these films. The temperature dependent magnetization (M-T) measurements reveal a paramagnetic-ferromagnetic transition at $T_C$ ~91K. The strong divergence between the zero field cooled and field cooled M-T curves suggests a strong clustered glass component in these films. These SSMO films show very sharp insulator metal transition (IMT) accompanied by a strong hysteresis (range 50-100K), where the resistivity drops by several orders of magnitudes just below the $T_{IM}$. This behavior resembles thermo-remnant magnetization in spin glasses, which are well known for their nonequilibrium slow dynamics such as long-time relaxation, aging, and memory behaviors. The observed glassy transport has been commonly attributed to the slow evolution of the phase conversions among competing phases coexisting in the material as a result of phase separation.

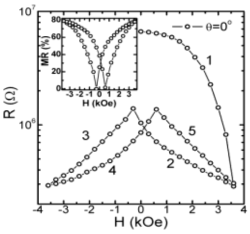


**FIGURE 1.** Magnetic field dependence of resistance and MR at 78K when the H is parallel to the current, which is in the plane (θ = 0º).

We measured the anisotropic magnetotransport properties as function the angle (θ) between the in-plane current (I) and the magnetic field (H). The applied current was always in the plane of the film. Figs. 1 & 2 show representative plots of the magnetic field driven isothermal resistance change (78K) for different angles (θ=0º and 90º) between H and I flowing through the film. As seen in the figure 1, when I is parallel to H (θ=0°) the resistance drops sharply on application of the magnetic field, resulting in low field colossal magnetoresistance (LF-CMR) ~99% at H=3.6 kOe. On reversing the magnetic field the resistance grows again but the virgin resistivity could not be attained even at H=0 kOe. Instead the maximum resistance was attained at H≈0.3 kOe. In the subsequent cycles of the magnetic field produced an irreversible growth and decay of resistance that resulted in a strong hysteresis. The LF-CMR corresponding to the resistance variation at θ=0° is shown in the inset of Fig. 1. The LF-CMR ~99% observed during the virgin cycle is reduced to ~80% (both at 3.6 kOe) during the subsequent ones. At θ=30° the magnitude of LF-CMR (at 3.6 kOe) is reduced during both the virgin (~90%) as well as subsequent cycles (~70%) while at θ=60°, these values decreases to ~45% and ~30% respectively. As θ is increased further, isothermal resistance decay as a function of the magnetic field is drastically reduced and the observed hysteresis disappears. When H becomes perpendicular to I (θ=90°) no hysteresis is seen, and the maximum LFMR measured at H=3.6 kOe in the virgin and subsequent cycles decreases to ~21% and ~7% respectively (Fig. 2). Our results demonstrate that the SSMO thin film on LSAT shows huge out-of-plane (OP) anisotropy in the electrical transport properties such as LFMR. To the best of our knowledge such huge anisotropy has not been reported in manganite thin films. It is also interesting to note that the strong hysteretic behavior of the resistance and MR observed at θ=0° disappears at θ=90°.

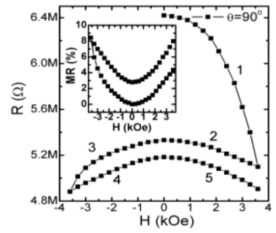


**FIGURE 2.** Magnetic field dependence of resistance and MR at 78K when H is perpendicular to the current (θ = 90º).

The observed huge anisotropic LFMR has been discussed in terms of the effects caused by the (a) magnetic domain motion in applied magnetic field, (b) different types of anisotropies, such as, magneto crystalline, shape and surface anisotropy that come into play in thin films, (c) the strong phase competition between FMM and AFM-COI phases and (d) the substrate induced strain.

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## REFERENCES

1. Y. Tokura, *Rep. Prog. Phys.* **69**, 797 (2006).
2. Y. Tomioka, H. Hiraka, Y. Endoh, and Y. Tokura, *Phys. Rev. B* **74**, 104420 (2006).
3. M. Egilmez, K. H. Chow, J. Jung, and Z. Salman, *Appl. Phys. Letters* **90**, 162508 (2007).
4. H. Oshima, K. Miyano, Y. Konishi, M. Kawasaki, and Y. Tokura, *Appl. Phys. Letters* **75**, 1473 (1999).
5. J. O'Donnell, J. N. Eckstein, and M. S. Rzchowski, *Appl. Phys. Letters* **76**, 218 (2000).