Magnetic Properties of MBE Grown $La_{0.6}Sr_{0.4}MnO_3$ Thin Films

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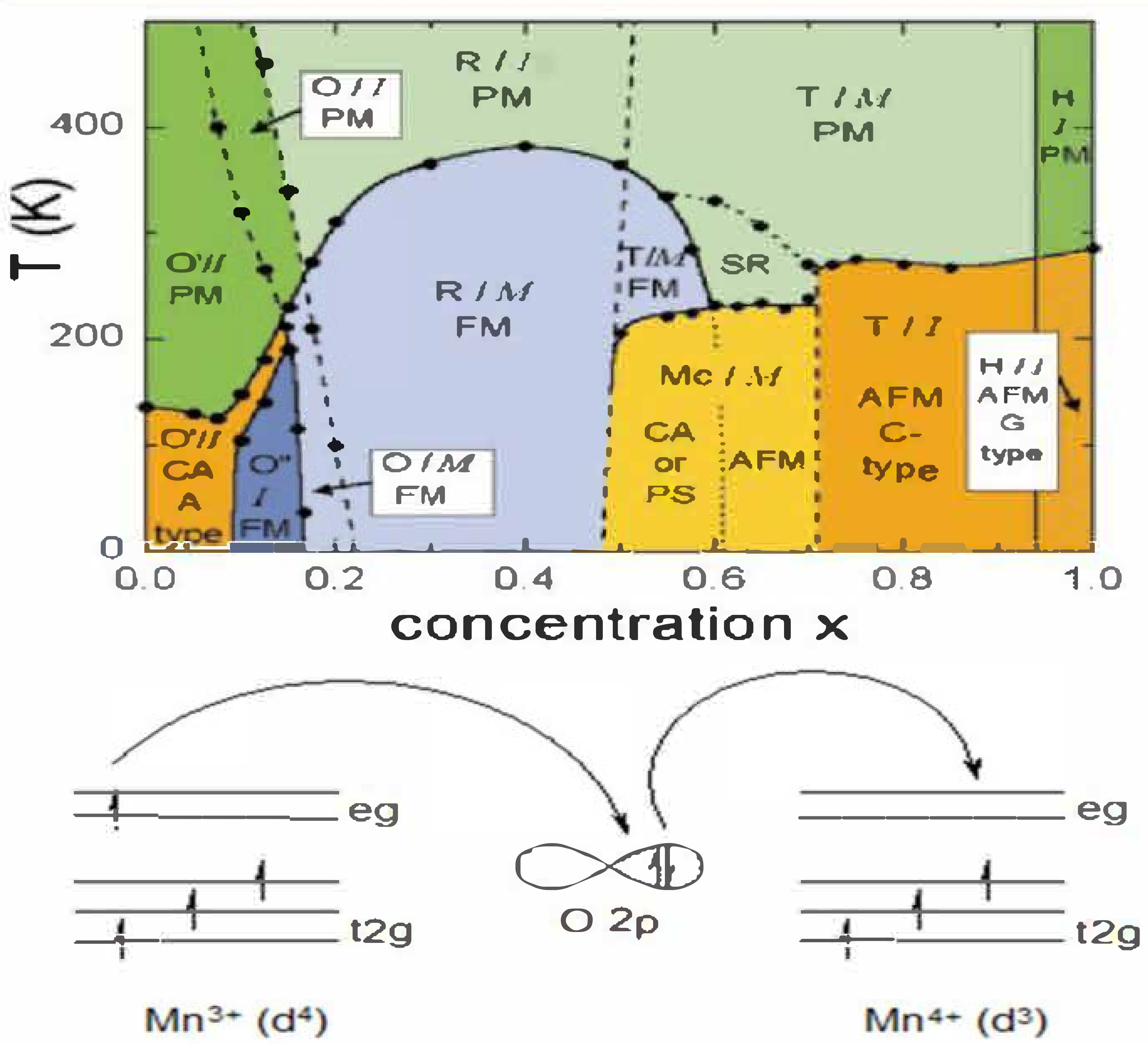
Abstract

This project investigates the magnetic properties of a $La_{1-x}Sr_xMnO_3$ (x = 0.40) sample of high quality. This sample was grown one atomic layer at a time by Prof. Warusawithana using UNF's Molecular Beam Epitaxy (MBE) machine. These magnetic properties are investigated over a range of temperatures from 5 to 400 K in fields up to 7 T. We make use of the techniques to analyze the sample to determine to a high degree of precision the critical temperature of the sample, we determined it to be 252 K.

We further identified the saturated magnetization, remnant magnetization, and coercive field at 5 K to be 0.00733 emu/g, 0.00563 emu/g and 0.0090 T respectively

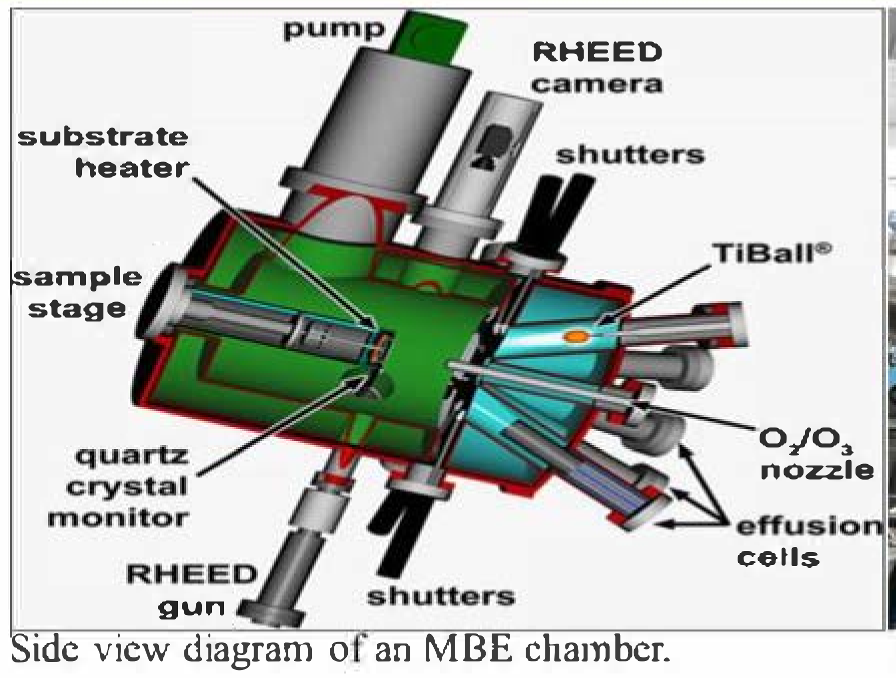
$La_{1-x}Sr_xMnO_3$ Bulk Phase Behavior



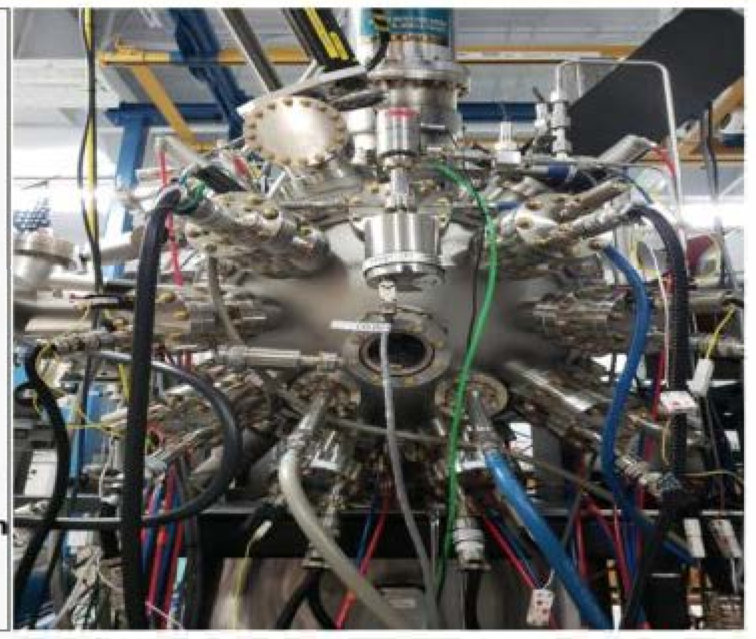
(Top) Bulk $La_{1-x}Sr_xMnO_3$ Phase diagram.
[Hemberger *et al*, PRB 66, 094410 (2002).]
(Bottom) Mechanism for double exchange interaction.

- $La_{1-x}Sr_xMnO_3$ has been extensively studied in bulk crystals with respect to temperature and strontium concentration.
- Undoped $LaMnO_3$ is a Mott insulator that is paramagnetic at high temperature and antiferromagnetic at low temperature.
- Around x = 0.4, $La_{1-x}Sr_xMnO_3$ behaves as a ferromagnetic conductor at low temperatures, however at high temperatures it transitions to a paramagnetic insulator.
- The conducting ferromagnetic state is favored at x = 0.4 at lower temperatures due to a double exchange interaction which reduces free energy by allowing for the delocalization of electrons across the spin-aligned Mn atoms

Molecular Beam Epitaxy



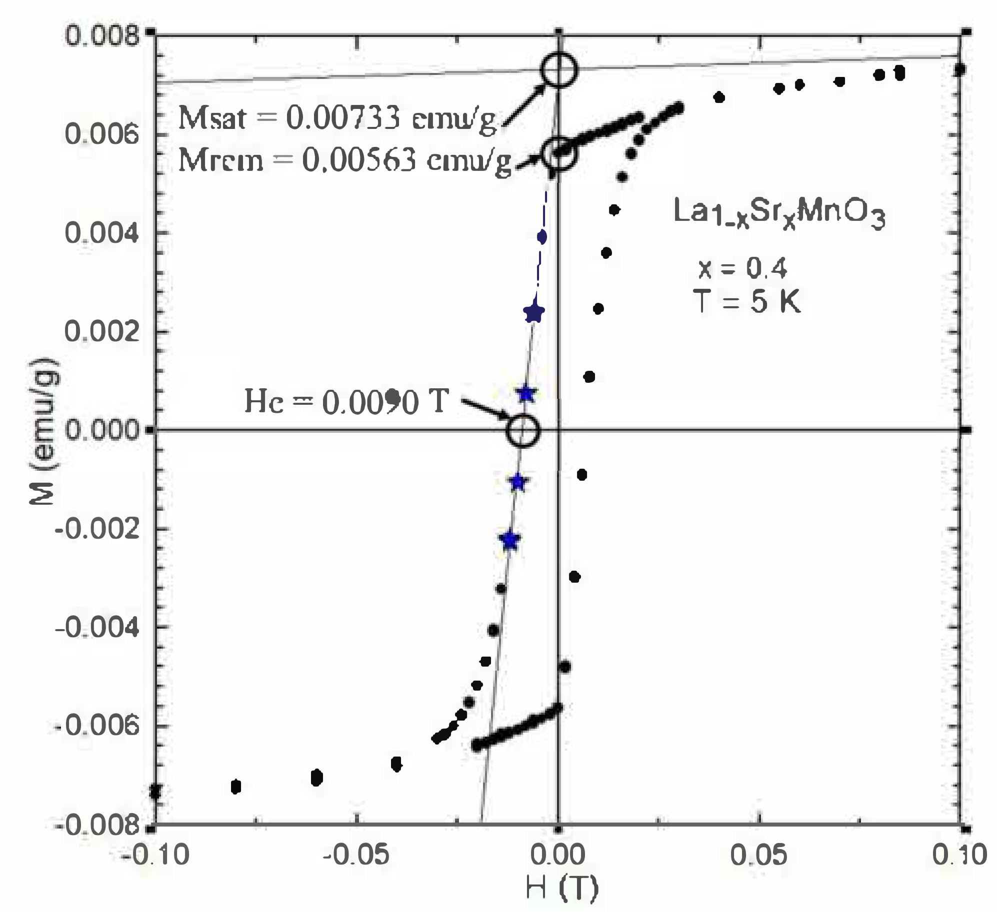
Side view diagram of an MBE chamber.



Front view picture of the chamber used in our growths.

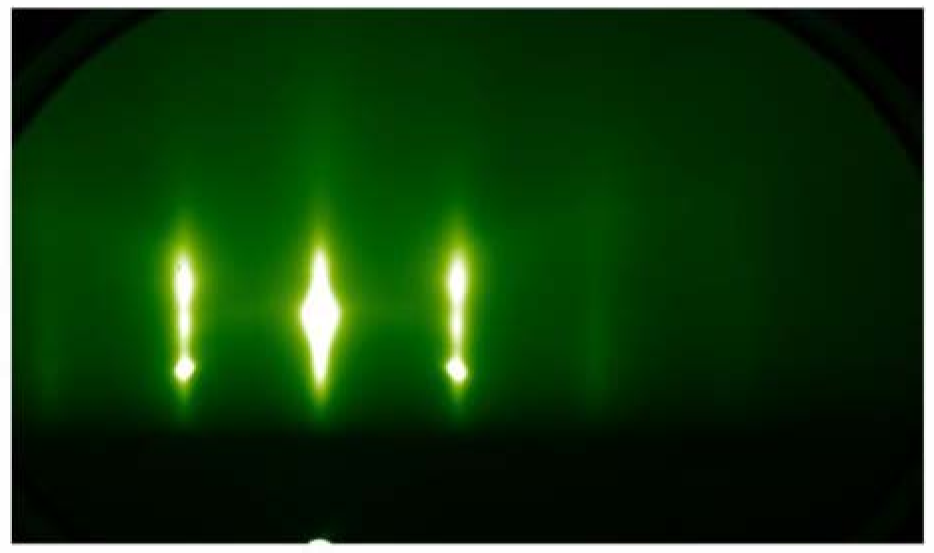
- Samples grown using Molecular Beam Epitaxy (MBE).
- Carefully calibrated molecular beams of constituent elements produce thin films one atomic layer at a time.
- Constituent elements sources are heated in effusion cells to evaporate material into the chamber, forming collimated molecular beams.
- Ozone was introduced into the chamber to form oxides, allowing us to keep the chamber pressure low (5×10^{-7} Torr) due to ozone's high oxidizing potential.

Ferromagnetic Hysteresis Loop at 5 K



Analysis of the data at low temperatures shows complete hysteresis for the concentration x = 0.4 confirming the expected ferromagnetic behavior predicted by the bulk sample.
The figure reveals the remnant magnetization (Mrem) to be 0.00563 (emu/g) and the saturated magnetization (Msat) to be 0.00733 (emu/g).
Finally the coercive field (Hc) is found to be 0.0090 T.

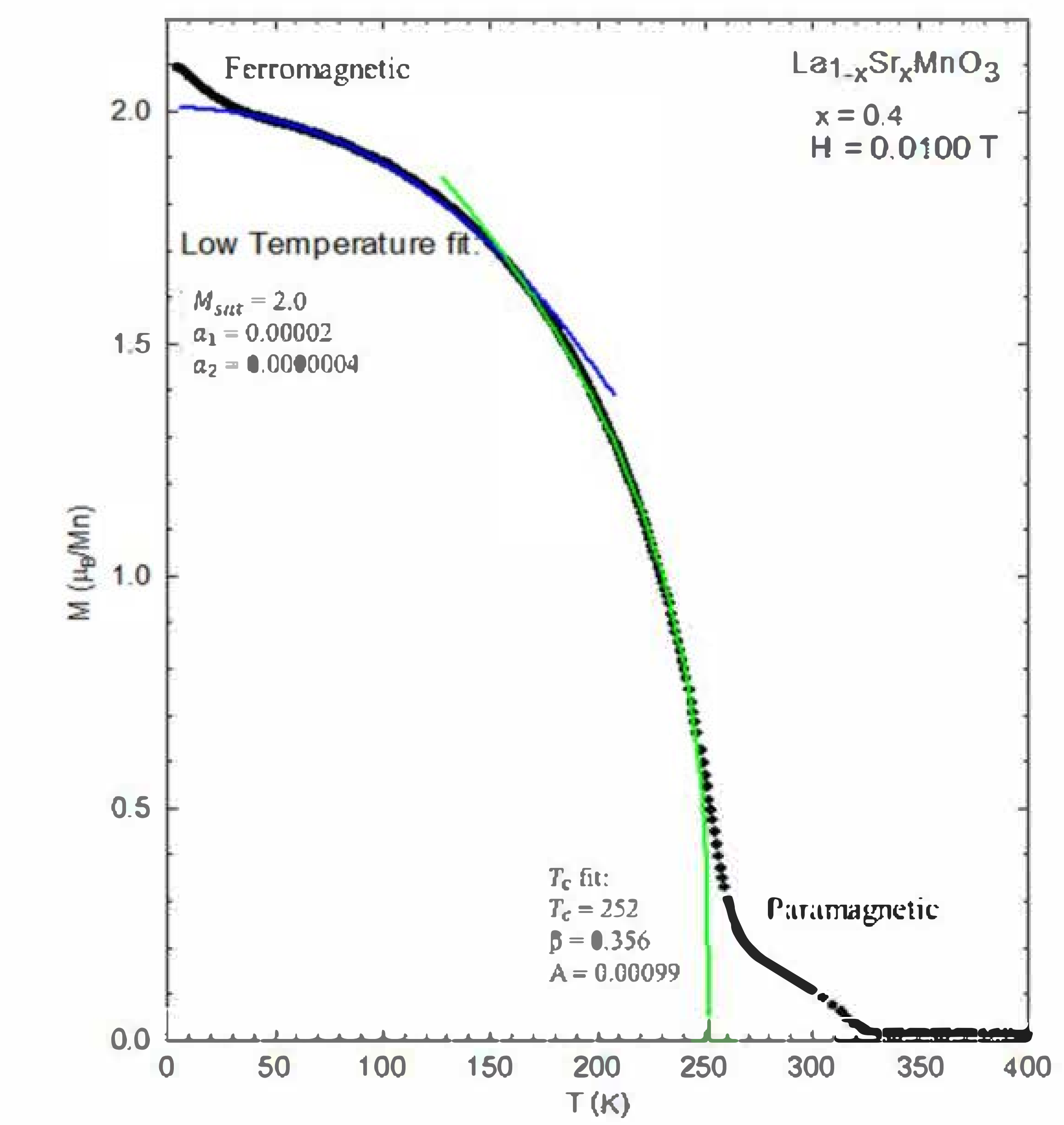
RHEED



LSMO x=0.4

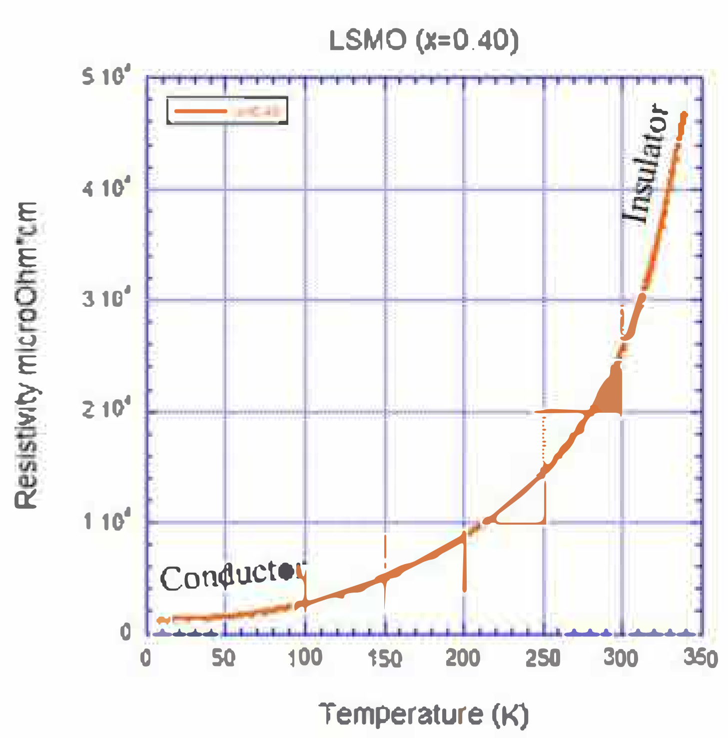
Reflection High Energy Electron Diffraction (RHEED) patterns taken nearing the end of growth reveal a well-strained 2-D system. images taken *in situ* during the growth of the films indicate epitaxial layer-by-layer growth. Transport data of the sample as well as expectations of the bulk sample indicate that at this concentration the material is a paramagnetic insulator at high temperature.

Ferromagnetic Transition Temperature



Magnetization versus temperature for the $La_{0.6}Sr_{0.4}MnO_3$ random alloy sample is shown. The key feature is a ferromagnetic transition near 252 K.
The fit at low temperature
$[M = M_{sat}(1 - a_1 T^{\frac{3}{2}} - a_2 T^{\frac{5}{2}})]$
is consistent with the decrease due to spin density waves.
The fit near Tc follows the standard power law behavior
$[M = A(T - T_c)^{\beta}]$.

Resistivity



When grown as a random alloy, where La and Sr atoms randomly occupy the A-site of the perovskite structure, $La_{0.6}Sr_{0.4}MnO_3$ has a conducting-ferromagnetic ground state. Its resistivity increases rapidly as a function of temperature. This indicating that at high temperatures it becomes a paramagnetic insulator, whereas at low temperatures it behaves as a ferromagnetic conductor.

Acknowledgements

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