Simultaneous Measurement of In-Plane and Out-of-Plane Magnetotransport in Anisotropic Thin Films

A. F. Hebard, A. Biswas, R. P. Rairigh, G. Singh-Bhalla, S. Tongay, T. Dhakal (UF, Physics)

Introduction

Thin films of strongly correlated electronic materials are often grown epitaxially on insulating planar substrates and typically have anisotropic properties that are usually not captured by edge-mounted four-terminal electrical measurements, which are primarily sensitive to in-plane conduction paths. We present an experimental study of anisotropic transport in phase-separated manganite thin films by employing an unconventional arrangement of contacting electrodes that allows for simultaneous determination of colossal magnetoresistance (CMR) associated with dc transport parallel to the film substrate and colossal magnetocapacitance (CMC) associated with ac transport in the perpendicular direction. We observe two distinct direction-dependent insulator-metal (IM) transitions. We also find a dielectric response which collapses onto a heretofore unobserved scale-invariant dependence over a large range of frequency, temperature and magnetic field.

Experimental

The experimental trilayer configuration, shown in Fig. 1a comprises a $(La_{1-y}Pr_y)_{0.67}Ca_{0.33}MnO_3$ (LPCMO) base electrode grown on an insulating $NdGaO_3$ (NGO)substrate, and subsequently covered with an AlO_x dielectric and an Al counterelectrode. The LPCMO sample under study is the base electrode rather than the middle layer as is typical for usual capacitance measurements. If the intervening AlO_x dielectric layer is of extremely high quality with negligible leakage, then frequencies can be chosen such that the ac conductance (complex capacitance) measurement is sensitive only to perpendicular transport [1].

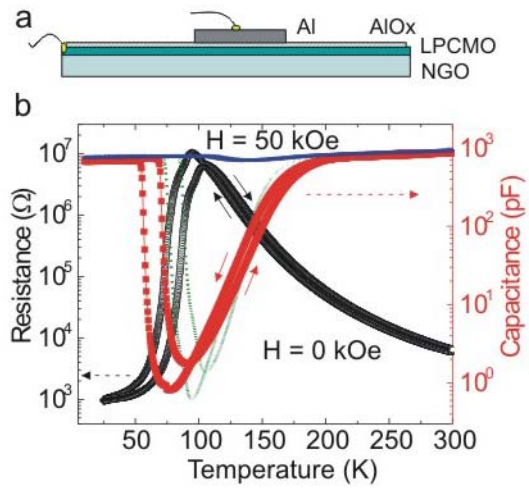

Figure 1: Parallel (4-terminal resistance, black) and perpendicular (2-terminal capacitance, red) transport measurements are made on the same (LPCMO) film shown as part of a trilayer configuration in (a). At 50 kOe (blue) the capacitance has increased from the zero field minimum by a factor of 1000 (colossal magnetocapacitance).

Results and Discussion

The separation in temperature shown in Fig. 1 of the resistance maximum and the capacitance minimum implies that the insulator-metal transition in the perpendicular direction takes place at a lower temperature compared to the parallel direction. The thin green line is a Maxwell-Wagner model fit which incorporates the temperature-dependent resistance as an input and therefore produces capacitance minima at temperatures coincident with the resistance maxima as would be true for an isotropic system. Cole-Cole plots of the complex capacitance data reveal a collapse of the data onto a single power-law curve (and hence scale invariance) with an exponent of 0.7 over a considerable range of temperatures, frequencies and magnetic fields [1].

Conclusions

The techniques described above can be applied to other anisotropic and layered thin-film systems and extended to the considerably higher fields that are available at the NHMFL.

Acknowledgements

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References

[1] Rairigh, R.P., *et al*., Nature Physics **3**, 551 (2007).