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Revealing direct linkage between bulk electric and microscopic magnetic properties of Manganites thin films

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One of the elegant ways to investigate the mysteries of complex exotic materials would be the application of scanning probe microscopes. Manganites are among the enigmatic materials with unique electronic and magnetic properties. These materials demonstrate strong electronic correlations, which results in a rich electronic phase diagram, including colossal electroresistance and magnetoresistance. In these systems it is known that current can induce a large reduction in resistivity but negligible variation in magnetization, which is counter-intuitive because the spin and charge are strongly coupled in manganites. Additionally, the role of chemical ordering of the dopants on the physical properties of manganites has been a question.

In order to reveal the microscopic mechanism of these phenomena Shen et al.[1,2] have carried out measurements on $(La_{1-y}Pr_y)_{1-x}Ca_xMnO_3$ thin films epitaxially grown on $SrTiO_3$, with attoMFM at low temperature and magnetic fields.

The results show that current does not alter the shape of the FMM domains, but induces tiny FMM domains which appear

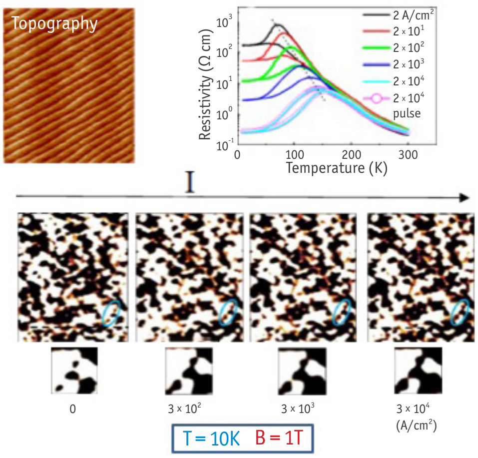

Figure 1: AFM/MFM Images of LPCMO thin film with various electric current, at low Temperature with high magnetic fields.

at critical regions to bridge large neighboring FMM domains (Fig 1). This works uncovers the underlying mechanism of the colossal electroresistance in the LPCMO system. In contrast to the previous assumption that current alters the shape of the FMM domains, it is demonstrated that the FMM domains remain unchanged after passing electric current. Instead, it is the appearance of a tiny fraction of FMM "bridges" that changes the total conductivity dramatically. This also solves the puzzle why current induces a drastic change of resistivity but minor variation of magnetization in the LPCMO system.

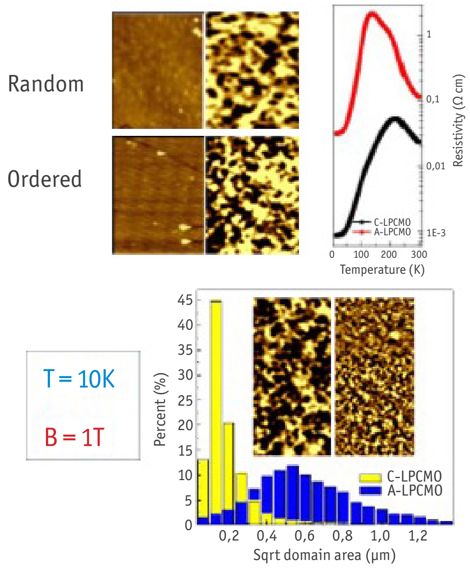

Figure 2: AFM/MFM Images of LPCMO thin film with random and ordered Pr doped system, at low Temperature with high magnetic fields

In Fig 2, the MFM images of random and ordered Pr doped systems demonstrate the difference in the domain size of the FMM phase, with a clear reduction of the length of electronic phase separation size for the ordered phase, which results in smaller resistivity and a higher metal–insulator transition temperature because the ferromagnetic metallic phase is more dominant at all temperatures below the Curie temperature.

These measurements illustrate the capability of applying MFM to reveal the microscopic mechanisms of electronic and magnetic ordering of exotic materials, helping to design materials with interesting electronic and spintronic applications.

References

[1] Nature communications 10.1038/ncomms11260
[2] Physical Review B 10.1103/PhysRevB.93.035111

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