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Report:

We have performed Linear Dichroism (LD) and Circular Dichroism (XMCD) in the absorption of soft x-rays at the Mn $L_{2,3}$ edges, as detected by total electron yield, to investigate the interface magnetism in ultrathin $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) films. The two techniques are complementary, allowing to investigate both the ferromagnetic (FM) and the antiferromagnetic (AF) phase. We have measured LSMO samples grown on different susbstrates, namely $SrTiO_3$ (STO), $LaAlO_3$ (LAO) and $NdGaO_3$(NGO). Therefore, the samples were under different strain conditions, and having different thicknesses, the metal-insulator transition was crossed at different sample temperatures. Therefore, the measurements were performed from room temperature down to 2 K. In addition, an external magnetic field has been used with the 7T superconducting magnet, to enhance or suppress the response from the (FM) phase and discriminate the AF from the FM contribution. The magnetic field was parallel to the incident photon beam, so that the if the applied field is strong enough, magnetization in the FM system is forced to align along the direction of the incident beam. Therefore, the FM contribution is suppressed because the spin system is orthogonal to both the vertical (V) and horizontal (H) polarization directions

First of all, we checked that the magnetic field of 1 T was enough to saturate the FM phase. Therefore, at each temperature we recorded XMCD spectra at different magnetic field (until 1T). The hysteresis cycles were also obtained from the XMCD measurements by the ratio between the pre-edge and the maximum intensity of the XMCD spectra taken at different external magnetic fields. Then we measured the LD by using two orthogonal linear polarization, V and H, of the synchrotron radiation with an incident angle of 30° from the sample surface. We made measurements above and below the magnetic transition temperatures of the samples, with decreasing and increasing the temperature.

We measured in total 7 different samples: two LSMO films deposited on LAO substrate with thickness of 100 unit cells (u.c.) and 30 u.c.; three LSMO films deposited on STO substrate with thickness of 50 u.c., 10 u.c. and 6 u.c.; two LSMO films deposited on NGO substrate with thickness of 9 u.c. and 6 u.c.

Typical results of LD(a) and XMCD(b), are reported in the figure below, together with the hysteresis loop in the bottom panels of (b).

On the basis of the results obtained during this experiment, we have written a paper accepted for publication in Physical Review Letters, where we demonstrate that LD on thin LSMO films grown on different substrates, allows identification of preferential $3d\text{-}e_g(3z^2\text{-}r^2)$ occupation, as a peculiar interface effect. Such a kind of preferential occupation, related just to the presence of the interface, contributes to suppress the double exchange mechanism. This surface orbital reconstruction is opposite to that favored by residual strain and is independent of dipolar fields, the chemical nature of the substrate and the presence of capping layers.

In addition, with this experiment we could correlate the Mn 3*d* orbital occupation with the magnetic properties of LSMO films, showing that the degradation of the magneto-transport properties originates from the stabilization of an AF insulating phase in turn driven by the interface/surface induced rearrangement of the Mn 3*d* orbitals. We have submitted a paper to Nature Materials, where we explain that the AF phase competes with the "bulk" FM phase in the framework of a phase separation scenario, the relative concentration depending on layer thickness and lattice distortion induced by epitaxial strain. The ferromagnetic phase anisotropy is mainly driven by the epitaxial strain induced by the substrate, whereas the interface seems to have the main role in the stabilization of the antiferromagnetic ordering perpendicular to the surface.

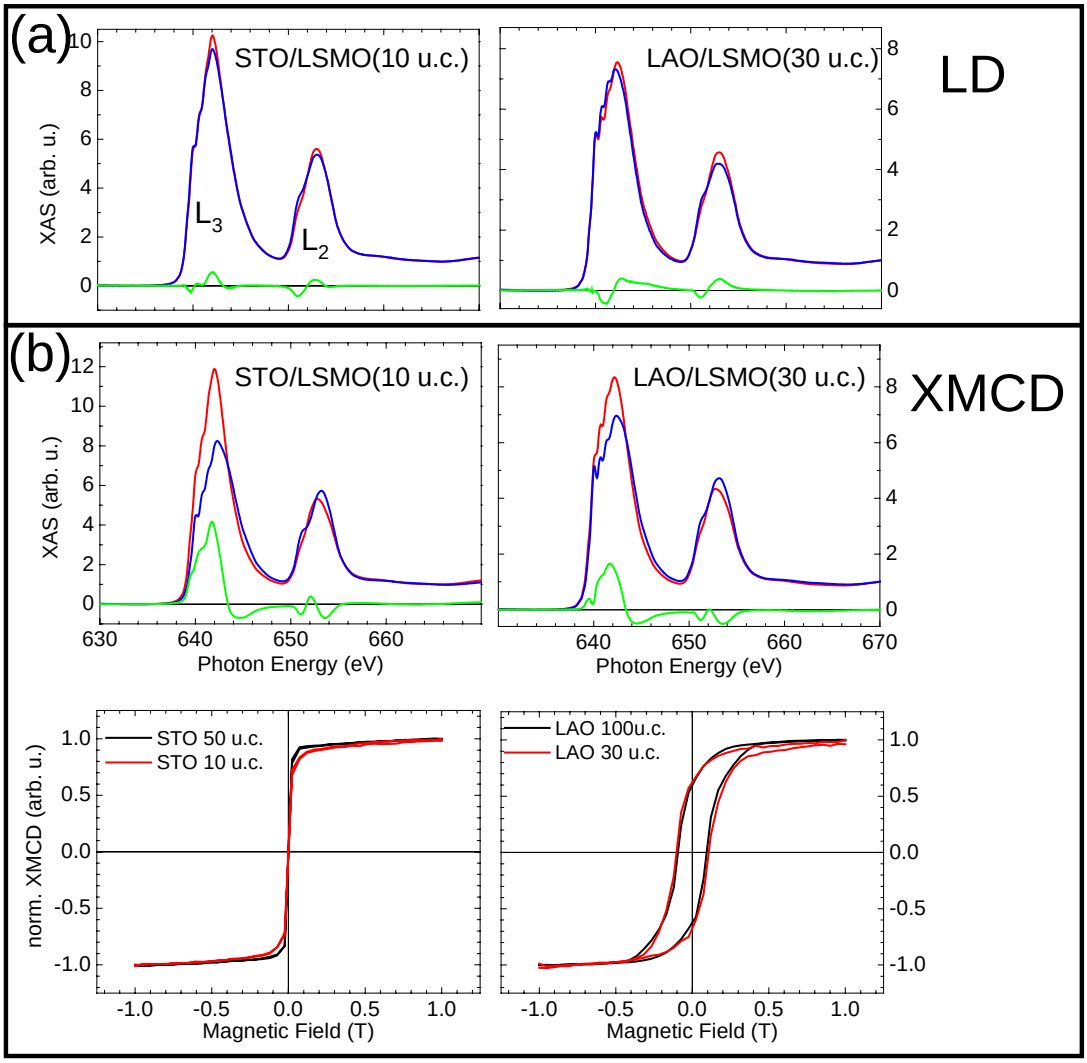

Figure caption. LD (a) and XMCD (b) results obtained in the case of LSMO film grown on STO substrate (left) and on LAO substrate (right), at temperature 10K and applied magnetic field B=1T. Both in Linear and in Circular Dichroism measurements the magnetic field B is applied along the photons direction. The hysteresis loops are obtained by the maximum peak intensity of the Circular Dichroism (about 642 eV) as a function of the applied magnetic field between B = –1T and B = 1T. In all the XAS measurements a linear background was fitted to the pre-edge region of the L_3 edge and subtracted from the spectra, which are then normalized to the edge jump set to unity above the L_2 edge. All the dichroic results are reported as a difference of the XAS measurements for the two different polarizations without any further normalization. The hysteresis loop curves are normalized to unity for a better comparison of the coercitive fields.