Spin and Angle Resolved Photoemission on $La_xSr_{1-x}MnO_3$ strained thin layers: an uniaxial half-metal

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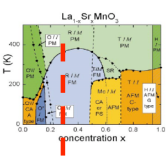
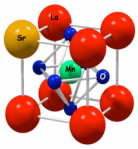
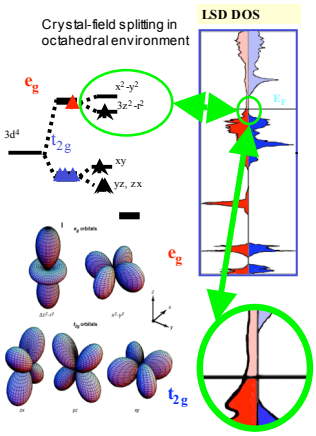
MOTIVATION

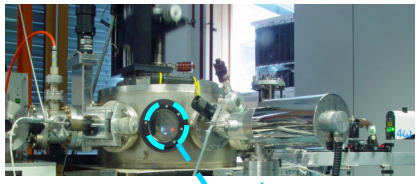
Among the Mn-oxide compounds, the mixed-valence manganites $La_xSr_{1-x}MnO_3$ (LSMO) have received particularr attention for their potentially useful applications. Besides the famous colossal magnetoresistive (CMR) behaviour, the notion of "half-metallic ferromagnet" is often cited for LSMO. From the experimental point of view, half metallicity does not show any clear electrical signature and is therefore not easy to determine. Photoemission-based spin-polarization measurements probe directly the spin-polarization of the removal states. Park et al. (PRL 81(1998)1953) reported spin polarization of 100±5% in LSMO and an insulating gap of 600 meV for the minority spins. However, this experiment was angle-integrated.

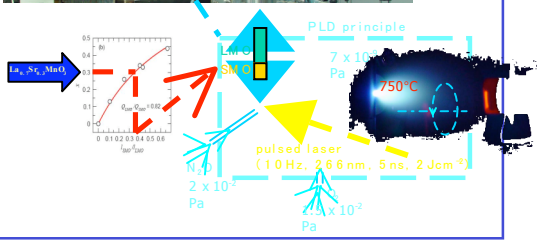






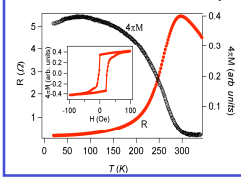
SAMPLE PREPARATION: PULSED LASER DEPOSITION



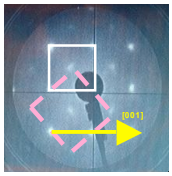


SAMPLE CHARACTERIZATION

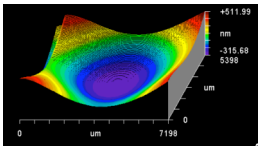
We spent much effort in manufacturing and characterizing 3D LSMO thin films suitable for ARPES measurements (P.R.Willmott, J.R. Huber : Rev. Mod. Phys. 72, 315 (2000)).
The surface, as determined by ex-situ AFM measurements, is of high quality with a step size not exceeding 2 Å. The sample Curie temperature (Tc) was found to be 297 K and appears to coincide with the minimum of the sample resistivity, which is typical for CMR materials. The stoichiometry was checked ex-situ with Rutherford Backscattering Spectroscopy. An important aspect in our experimental set-up was the in-situ sample transfer to the spin-resolved experimental station at the Surface and Interface Spectroscopy beamline at the Swiss Light Source (SLS). The LEED measurements in the experimental chamber showed a clear 1X1 pattern with $\sqrt{2}x\sqrt{2}$ surface reconstruction.



Temperature dependence of resistivity (red) and magnetization (black) of a 120 nm-thick LSMO thin film. The magnetic hysteresis curve is in the inset.



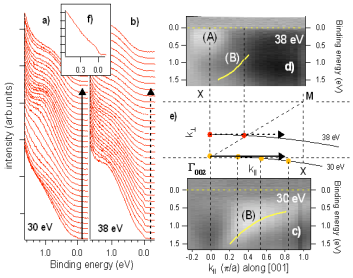
LEED pattern measured at 77 eV



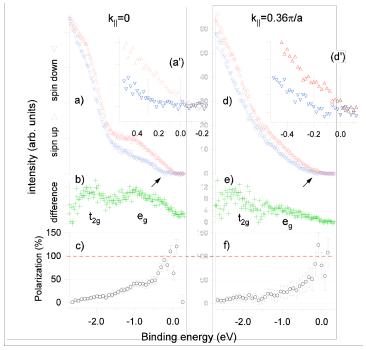
Strained films on $SrTiO_3$ tetragonal distortion (0.1%)

RESULTS

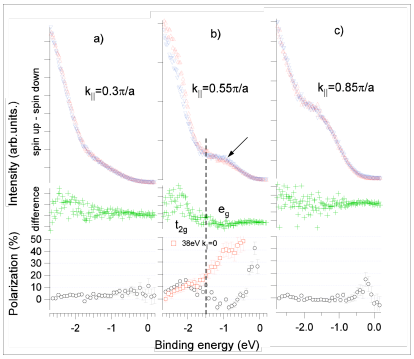
The normal emission spin-integrated ARPES at 30 and 38 eV seen in Fig. c and d shows a dispersion of two energy bands, labelled A and B.
We already reported [M.C. Falub et al., PRB, accepted, M. Shi et al., PRB, 70, 140407 (2004)] that off-normal photoemission at hν=30eV is characterized by a 2D-like energy band with the x^2-y^2 orbital symmetry, dispersing in directions parallel to the surface. Whereas the $3z^2$- r^2 orbital is a 1D-like band dispersing perpendicular to the surface.



Spin resolved EDC for 38eV in normal emission (a-c), and off normal emission (d-f). The half-metallic gaps (highlighted with vertical bars inside the insets a' and d') does shrink from 300 meV in normal emission to 200 meV in off normal emission. At the same time the relative intensity of the e_g band is lowered by a factor of 3-4, clearly indicative that the density of states of the spin-up electrons is smaller than in normal emission.



Spin resolved EDC's at 30 eV for tree distinct points along the Γ-X direction in the (001) mirror plane show poor spin polarization. Maximum spin polarization (~40%) appears to be for $k_{//}$ ~0.5 π/a seen in b. Here the polarization for 38 eV and normal emission is plotted (red) in order to compare spin polarizations at equivalent points in k-space but in different experimental geometries.



CONCLUSION

We found that our sample shows genuine half-metallic behaviour with the half-gap of 300 meV in one point of the k-space, namely at the Fermi surface in normal emission. The off-normal photoemission shows poor spin-polarization reflecting uniaxial half-metallicity.

This work was performed at the SIS, COPHEE and SIM beamlines of the Swiss Light Source, Paul Scherrer Institut, Villigen and PSI/ETH Tandem accelerator (CH).

SLS Swiss Light Source