Emergence of 2D electronic states at Fe_xO_y/STO interfaces

P. M. Düring[1], T. Krieg[1], A. Fuhrberg[1], P. Rosenberger[1], Seema[1], F. Alarab[2], F. Lechermann[3], L. Baumgarten[4], V. N. Strocov[2], and M. Müller[1]

[1] *Department of Physics, University of Konstanz, D-78457 Konstanz*
[2] *Paul Scherrer Institute, Swiss Light Source, CH-5232 Villingen PSI*
[3] *Institute of Theoretical Physics III, Ruhr University Bochum, D-44780 Bochum*
[4] *Forschungszentrum Jülich GmbH, PGI-6, D-52425 Jülich*

Oxide interfaces are emerging as one of the most interesting systems in condensed matter physics as they exhibit a multitude of physical phenomena such as the 2D electron/hole gas, superconductivity, or the Spin Hall effect. One of the main processes that controls the emergence of 2D electronic states in oxide systems is the oxygen exchange between the film and the substrate. The tunability of the oxygen transfer using different growth parameters opens up the possibility to unravel unexplored properties.

Using our UHV-MBE system, we grow high-quality ultrathin Fe-oxide films on $SrTiO_3$ substrates by systematically varying certain growth parameters. Performing in situ X-ray Photoelectron Spectroscopy and Low Energy Electron Diffraction enables the analysis of the electronic properties and crystalline structure of ultrathin Fe_xO_y films directly after the growth without any atmospheric contamination.

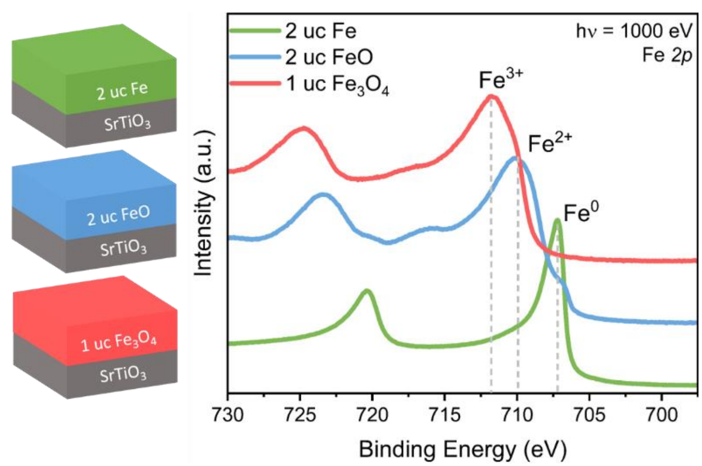

Fig. 1: *XPS spectra of the spin-orbit split Fe $2p_{3/2}$ and $2p_{1/2}$ doublets of the grown Fe_xO_y films with Fe metal (Fe^0), FeO (Fe^{2+}) and magnetite ($Fe^{2+,3+}$).*

The present work discusses the effect of different growth temperatures, substrate annealing procedures, and film thicknesses of the Fe_xO_y films on the interfacial properties like oxygen vacancies. The oxidation state of Fe_xO_y as well as the concentration of defects in $SrTiO_3$ strongly influences the valence band alignment. Using synchrotron radiation, resonant photoelectron spectroscopy measurements reveal the emergence of different 2DESs at the Fe_xO_y/STO interfaces. These results open up the possibility to control the 2D interface properties by tuning such growth parameters. In a further step, the magnetic state of this proximity-coupled 2D system is expected to reveal the dimensionality-driven dependency on spin fluctuations around the critical temperature.

References:

[1] A. Ohtomo, H. Y. Hwang, *Nature* **427**, 423-426 (2004).
[2] S.A. Chambers et al., *Chem. Mat.* **27**, 4093-4098 (2015).
[3] Q. Fu, T. Wagner, *J. Phys. Chem. B* **109**, 11697-11705 (2005)
[4] P. Lömker *et al.*, *Phys. Rev. Mater.* **1**, 062001 (2017)
[5] M. H. Hamed *et al.*, *J. Mater. Chem. C* **8**, 1335-1343 (2020)