Universal fabrication of 2D electron systems in functional oxides

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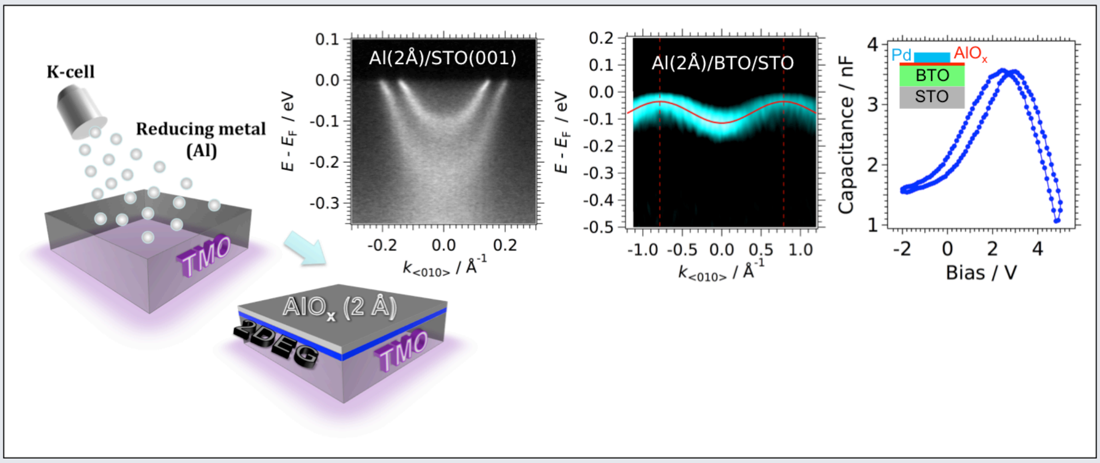
Two-dimensional electron gases (2DEGs) in transition metal oxides (TMOs) can show metal-to-insulator transitions, superconductivity, magnetism, or spin-polarized states, and are thus an active field of research promising for applications beyond semiconductor technology. However, their fabrication and use, essentially limited to heterostructures based on $SrTiO_3$ (STO), are hampered by the need of growing complex oxide layers using evolved and expensive techniques.



In the framework of the ELECTROX project, we developed a new, extremely simple, and essentially universal method to fabricate 2DEGs in functional oxides –see figure above. It consists in the deposition of a thin layer (a few Ångstrom) of an elementary reducing agent, such as pure Al, over the surface of an oxide in vacuum. By a redox reaction, the reducing agent pumps oxygen from the substrate, oxidizes into an insulating passivation layer, and simultaneously dopes the first atomic planes of the underlying oxide, thus forming a pristine 2DEG. The quantum-well states of such a 2DEG, for instance in STO, are then directly measured using angle-resolved photoemission spectroscopy (ARPES). As a novel application, we generate a 2D metallic state at the surface of the ferroelectric insulator $BaTiO_3$. (BTO) Such hitherto unobserved coexistence of surface conductivity and bulk ferroelectricity, characterized by the capacitance hysteresis loop, is promising for functional devices using ferroelectric resistive switching.

This new, simpler and cheaper, fabrication route for two-dimensional electron gases is thus adaptable to numerous functional oxides, scalable to industrial production, and ideally suited for the realization of electronic devices and for applications that rely on charge or spin injection.

T. C. Rödel, F. Fortuna, S. Sengupta, E. Frantzeskakis, P. Le Fèvre, F. Bertran, B. Mercey, S. Matzen, G. Agnus, T. Maroutian, P. Lecoeur, and A. F. Santander-Syro, *Universal Fabrication of 2D Electron Systems in Functional Oxides*, Advanced Materials 28, 1976 (2016)

Résultats obtenus dans le cadre du projet ELECTROX financé par le thème 1 du LabEx PALM et porté par Andrés Santander-Syro (CSNSM), François Bertran (SOLEIL) et Marc Gabay (LPS).