Programme "Bourse Jean D'Alembert"
Université Paris-Saclay

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Host Lab : Unité Mixte de Physique CNRS/Thales

Lectures on Novel Phenomena at Oxide Interfaces

Lecture 1. Introduction to the physics of oxide interfaces

Tuesday June 6, 14:30-16:30, room 1C-50 (1st floor, Thales-RT entrance building)

In 3d transition metal oxides (TMO), the unscreened Coulomb repulsion between the localized 3d electrons gives rise to strong correlations in the electron system, which underlie the delicate entanglement between the various interactions in these materials, and lead to a multiplicity of competing phases with comparable characteristic energies. Indeed, almost every broken symmetry ground-state can be found in these materials, including superconductivity, magnetism, ferroelectricity, multiferroicity, etc. This entanglement is probably at the origin of the complex phase diagrams and of the inhomogeneous ground states and of the complex (in some cases giant) collective responses exhibited by these materials upon small perturbations, whose understanding remains a major challenge of condensed matter physics for the years to come. In recent years there has been a Oxide interfaces show extraordinary properties that are not found in the constituent materials individually. The archetypal example is the metallic state at the interface between two band insulators, LAO and STO, which was discovered in 2004 and launched the field of Oxide Interfaces. The possibilities to nucleate emergent electronic states at interfaces can be enormously expanded if correlated transition metal oxides, instead of inert band insulators are used to create them. This, together with the possibility of engineering their interfaces with atomic precision, has raised the hope of tailoring their electronic structures into new device concepts (spintronic and spin-orbitronic devices, memristors, etc) for a future oxide electronics. In this first lecture we will revise introductory concepts of the physics of TMO, and describe the most salient results which have fuelled the launch of the rapidly expanding field of oxide interfaces.

Lecture 2. Novel functionalities at oxide interfaces

Monday June 12, 14:30-16:30, room 2C-50 (2nd floor, Thales-RT entrance building)

The growing interest on the new electronic states building up at the interfaces between correlated oxides as the result of the various forms of symmetry breaking has prompted a strong effort driven to functionalize them into novel device concepts. However, the technological potential of oxide interfaces has not been fulfilled yet, partly due to the incomplete understanding of the complex physics involved but also to the lack of simple device concepts with externally tunable responses. In this lecture we offer a series of examples of our recent work showing that interfacially induced magnetism at oxide interfaces can be used to tailor novel functionalities in magnetic tunnel junctions. In particular we will show that the spin reconstruction at the interfaces drives them into a novel magnetic state which acts a spin filter similar to the one observed with ferromagnetically insulating barrier resulting from different barrier heights for both spin orientations.

Lecture 3. Novel proximity phenomena at superconducting oxide interfaces

Monday June 19, 14:30-16:30, room 2C-50 (2nd floor, Thales-RT entrance building)

More than twenty years after the discovery of the High Tc Superconductivity there are still many open questions regarding the origin and mechanism of the phenomenon. In this lecture we will review a number of basic problems in the physics of the cuprates with special emphasis on the description of the pseudogap state, phase separation phenomena and the importance of magnetic excitations in the reconstruction of the Fermi surface. Next we will describe the behaviour of superconducting layers at epitaxial interfaces. In particular we will address the interplay between ferromagnetism and superconductivity. The antagonistic character of both long range orders suppresses superconductivity at F/S interfaces, due to the exchange field effect on the antiparallel spins of singlet Cooper pairs. However, in the presence of spin active F/S interfaces, spin-polarized triplet correlations have been theoretically predicted to spread superconductivity over long distances into the ferromagnet. Recent experiments on multilayers combining conventional superconductors and ferromagnets have indeed shown unusually long range proximity effects, supportive of that type of equal-spin triplet correlations. Interestingly, these would allow for superconducting spin currents, in which the spin carried information is protected by superconducting correlations, thus opening the door to a new class of superconducting spintronic devices. Finally we will describe the role of proximity phenomena on novel strategies of vortex pinning in High Tc superconductivity of possible applied interest.

Lecture 4. Nanoionics at oxide interfaces

Monday June 26, 14:30-16:30, room 2C-50 (2nd floor, Thales-RT entrance building)

Oxygen vacancies are the most common defect in oxide perovskite oxides. Important applications are associated to their controlled generation and transport in electrochemical energy (fuel cells and batteries) and memory (memristors) devices. At interfaces oxygen vacancies can accumulate under the action of external electric fields and, especially in nanostructures where sample size becomes comparable to migration length, be the source of novel, yet unreported, functionalities. In this lecture we will discuss the dynamic control of the vacancy profile in the nanometer thick barrier of a ferroelectric tunnel junction. Oxygen vacancies generated at an electrochemically active electrode accumulate towards the asymmetric interfaces of a ferroelectric tunnel barrier under the action of an external electric field and their ensuing doping effect modify the screening of the polarization charges. Novel memory devices for oxide electronics can be envisaged associated to electrochemically controlled polarization states in a ferroelectric tunnel barrier generated by the independent switching of the oxygen vacancies and of the ferroelectric polarization.

Field effect experiments on oxides using ionic liquids have enabled the exploration of their rich phase diagrams. Conventional understanding of the electrostatic doping is in terms of modifications of the charge density to screen the electric field generated at the double layer. However, there is an open debate on the true nature, electrostatic vs electrochemical, of the doping with ionic liquids. In this lecture we will discuss the doping mechanism of ionic liquid gating. Beyond providing evidence of the importance of chemical doping in EDL gating experiments with superconducting cuprates, we will discuss that interfacing correlated oxides with ionic liquids enables a delicate control of oxygen content paving the way to novel electrochemical concepts in future oxide electronics.

Attendance is free but registration is mandatory by sending an email to Javier Villegas javier.villegas@cnrs-thales.fr

How to reach UMPhy CNRS/Thales in Palaiseau