Nanoscale effects at complex-oxide superconducting/ferroic hybrids

Javier E. Villegas[1], A. Crassous[1], C. Visani[1], Z. Sefrioui[2], R. Bernard[1], S Fusil[1], K. Bouzehouane[1], J. Tornos[2], C. León[2], J. Briatico[1], M. Bibes[1], A. Barthélémy[1,3], J. Santamaría[2]

[1]Unité Mixte de Physique CNRS/Thales, Palaiseau, France
[2] GFMC, Universidad Complutense de Madrid, Spain
[3] Université Paris Sud, Orsay, France

javier.villegas@thalesgroup.com

Abstract

The physical properties of hybrid structures in which dissimilar materials are combined may radically differ from those of the individual constituents, as novel –sometimes unexpected– behaviors arise due to competing interactions. The latter are enhanced by the reduced dimensionality, the confinement, and the intimate (nanoscale) contact at the interfaces. Interestingly, external stimuli having moderate effects on each of the constituents may on the contrary induce dramatic effects in the hybrid structure, as they break a delicate balance resulting from the interface interactions. This allows engineering artificial materials with new functionalities. Oxide perovskites offer much potential for this, due to the large variety of isostructural materials available which exhibit different ground states (high-Tc superconductors, insulators, ferroics), and owing to the possibility of combining them in high-quality heterostructures [1].

One interesting possibility is to couple one of the constituents' sensitivity to external stimuli (e.g. electric or magnetic fields) to a measurable, strongly varying physical property of the other constituent (e.g. the electrical resistance in a superconductor). We will show an example of this in the first part of the talk. We exploit the possibility for oxide superconductors of varying the superconducting critical temperature under the application of an electrostatic field. This effect is produced here in heterostructures that combine a large-polarization ferroelectric ($BiFeO_3$) and a high-temperature superconductor ($YBa_2Cu_3O_{7-x}$). We demonstrate that this particular system allows for an unusually large modulation of the critical temperature upon reversal of the ferroelectric polarization by the momentary application of an electric field [2,3]. This enables one to effectively switch "on" and "off" high-temperature superconductivity. Furthermore, through this mechanism and owing to the ability to reversibly design the ferroelectric domain structure, we show that it is possible to produce a nanoscale modulation of the superconducting condensate [2]. This opens new possibilities for superconducting nano-electronic devices, which may exploit flux quantization [4,5] and Josephson coupling effects.

Another interesting possibility is to literally merge the most distinctive property of each of the constituents in order to observe truly hybridized behaviour. In the second part of the talk, we will show an example on how to unite the long-range phase-coherent charge transport characteristic of superconductivity and the spin-polarized charge transport characteristic of ferromagnetism, which may open the door to novel spintronic devices [6]. This is demonstrated in experiments with heterostructures that combine $YBa_2Cu_3O_{7-x}$ and the half-metallic ferromagnet $La_{0.7}Ca_{0.3}MnO_3$. [7]

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