Superconductivity and magnetism living apart together?

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The interface between two insulators is found to display ferromagnetism and superconductivity.

Subject Areas: Strongly Correlated Materials
FIG. 1: (a) The LaAlO$_3$/SrTiO$_3$ interface. At the interface, a polar discontinuity between neutral SrTiO$_3$ planes and charged LaAlO$_3$ planes produces a diverging potential. For LaAlO$_3$ thicknesses above three unit cells, an electronic reconstruction occurs, transferring from the LaAlO$_3$ surface to the interface $1/2$ electron per unit cell [13]. (b) From Dikin et al. [4], hysteresis in the magnetic-field dependence of sample resistance for different temperatures at a fixed gate voltage, $V_g = -100$ V. (c) Schematic of the phase separation scenario. Pavlenko et al. [10] propose that ferromagnetism is linked to oxygen vacancies, which locally produce an increase in carrier density favoring localized ferromagnetic regions (yellow), and that the electronic reconstruction is responsible for the metallic and superconducting regions. (Credit: (a,c) S. Gariglio; (b) D. A. Dikin et al.)

The report of Dikin et al. features a ten-unit-cell LAO film grown by pulsed laser deposition at an oxygen pressure of $10^{-3}$ mbar, a pressure regime that in previous studies led to superconducting samples (notice, however, that no in situ oxygen annealing was used here). While it is clear that an oxygen-starved growth environment favors 3D metallicity at the interface because of the creation of a large amount of oxygen vacancies, the occurrence of ferromagnetism may be linked not only to the used oxygen growth pressure but also to inhomogeneities in the doping profile, in directions both normal and parallel to the interface.

Analyzing the longitudinal and Hall resistances as a function of the gate voltage used to control the carrier density, Dikin et al. suggest that two independent electronic gases contribute to the conduction at the interface. The observed hysteretic behavior of the magnetoresistance, limited to very low temperatures in the superconducting region [$T_c(R=0) < T < T_c$ onset] and slightly above [see Fig. 1(b)], may suggest that superconductivity and ferromagnetism originate from the same phase. Superconductivity and ferromagnetism are, in general, exclusive phenomena. Superconducting ferromagnetic systems have, however, been found, albeit with a complex order parameter. A notable example is UGe$_2$[12], where superconductivity arises from the same electrons responsible for ferromagnetism.

The variety of phenomena observed at the LAO/STO interface is very promising for the use and possible tuning and control of the interface properties. At the same time, several key, fascinating questions are open, from the detailed understanding of the parameters controlling the material ground state and possible phase separation to questions related to the nature of the superconducting state. Further detailed studies are necessary to understand whether this interfacial system has the key ingredients necessary to allow for a mixed ground state.

References
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Stefano Gariglio is a Researcher in the Condensed Matter Physics Department at the University of Geneva. After his studies in Genoa (Italy), he obtained his Ph.D. in 2003 at the University of Geneva. His research interests are the physics of complex oxides, in particular, phenomena at interfaces and heterostructures, and their integration into functional devices.

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