Artificial oxide two-dimensional electron systems

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Advances in growth technology of oxide materials allow single atomic layer control of heterostructures. In particular delta doping, a key materials' engineering tool in today's semiconductor technology, is now also available for oxides. This offers the opportunity to create novel quantum systems, where various functionalities can be introduced by design.

Here I will present several examples of engineered oxide 2DES by combining band-insulating oxides characterized by different functionalities [1-4], including: ferromagnetic, ferroelectric, coupled ferromagnetic/ferroelectric and topological oxide 2DES.

The first example, is the realization of a fully electric-field-tunable spin-polarized and superconducting quasi-2D electron system (q2DES), that can be artificially created by inserting a few unit cells of delta doping EuTiO3 antiferromagnet at the interface between LaAlO3 and SrTiO3 or KTaO3 oxides. Spin polarization emerges at the Lifshitz transition and is due to the exchange interaction between the magnetic moments of Eu-4f and of Ti-3d electrons.

The second example is the realization of ferroelectric 2DEG by epitaxial growth of LaAlO3 on Ca-doped (1%-2%) SrTiO3 single crystals or by insertion of a ferroelectric layer between LaAlO3 and STO or LaAlO3 and KTO, like KNN. A ferromagnetic and ferroelectric 2DEG ca be engineered introducing few unit cells of EuTiO3 between LaAlO3 and Ca-doped STO. I will provide evidences of ferromagnetism, ferroelectricity and coupled ferromagnetism/ferroelectricity from magneto-transport and Hall effect measurements, polarization vs back gate electric field, and in particular by polarization dependent x-ray absorption spectroscopy.

A third example is the realization of a 2DES characterized by magneto-transport properties similar to gapped topological insulators [4], which combine time reversal, inversion and rotational symmetry breaking.

Our findings provide new opportunities in quantum matter and quantum applications stemming from the interplay between ferroelectricity, ferromagnetism, superconductivity and Rashba spin-orbit coupling in an oxide 2DEG.

References

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