The challenge of oxide nanoelectronics

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Complex oxide interfaces [1] exhibit a wide range of properties that are both scientifically interesting and technologically promising. For information technologies, it is important to be able to control these properties at the smallest possible length scales. In the last decade there have been remarkable advances in the techniques for growing high-quality epitaxial oxide films. By combining atomic-laser deposition with high-pressure RHEED, complex oxides can now be growth with monolayer precision and nearly atomically sharp interfaces.

The interface between $LaAlO_3$ and TiO_2-terminated $SrTiO_3$, first reported by Ohtomo and Hwang [2], exhibits interfacial conduction with relatively high mobility. The conducting interface inherits all of the properties of $SrTiO_3$ (metallic, insulating, superconducting, ferroelectric) and adds magnetism [3]. An important challenge centers around controlling these properties at near-interatomic scales [4, 5], and understanding how to exploit this control for new science and technology. So far, nanoscale transistors [5], rectifying junctions [6], single-electron transistors [7], and photoconductive junctions [8] have been created using a conductive atomic-force microscopy technique.

An important new theoretical approach to quantum computation exploits topological phases of matter that are stable against a wide variety of perturbations. $LaAlO_3/SrTiO_3$ nanostructures combine many of the properties believed to be essential for supporting Majorana fermions [9]. Our recent investigations of $LaAlO_3/SrTiO_3$ nanowires show that superconductivity persists in the extreme quasi-1D limit. However, it remains to be seen if this system is in fact suitable for topological quantum computation.

Quantum simulation has seen tremendous advances in recent years using ultracold atoms. Using $LaAlO_3/SrTiO_3$, it may be possible to create a solid-state quantum simulator that is capable of mapping into a wide class of Fermi-Hubbard Hamiltonians. The ability to perturb about a superconducting state make this system especially interesting for this application.

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