Surface Phase Transitions of Layered Perovskite $\text{Ca}_{2-x}\text{Sr}_x\text{RuO}_4$

Rob G. Moore, Jiandi Zhang, Ismail, S. V. Kalinin, J. Guo, A. P. Baddorf, R. Jin, D. G. Mandrus, E. W. Plummer

Department of Physics and Astronomy, The University of Tennessee, Knoxville, Tennessee 37996-1200

Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6057

Department of Physics, Florida International University, Miami, Florida 33199

What We Do...
Investigate the surface behavior of layered Calcium-Strontium Ruthenate Crystals, $\text{Ca}_{2-x}\text{Sr}_x\text{RuO}_4$, by a combination of electron spectroscopy and scanning probe microscopy techniques.

Why We Do It...
Strong coupling between electronic, lattice, orbital and spin degrees of freedom in transition metal oxides has attracted significant interest in exploiting their immense potential for oxide electronic devices with novel functionalities.

Doped transition metal oxides in general have a competition between ground states similar in energy creating materials with a wide array of exotic phases such as colossal magnetoresistance and superconductivity. In particular, substitution of solvant $\text{Ca}^{2+}$ for $\text{Sr}^{2+}$ controls the bandwidth of the material allowing an opportunity to study the evolution from an unusual p-wave superconductor ($x=2$) to an Antiferromagnetic Mott-type insulator ($x<0.2$) with the Mott metal-insulator transition temperature strongly dependent on doping.

The layered perovskite structure is amenable to cleaving. Breaking translation symmetry by the creation of a surface in strongly coupled systems is a controlled way to study the coupling between the various degrees of freedom and the possible creation of new phases.

Understanding the fundamental physics of reduced dimensionality involved in surface/interface properties is vital for the realization of materials with desired transport properties necessary for the next generation of electronic devices.

How We Do It...
Surface Electronic Structure – STM

STM reveals the local electronic density of states near the Fermi Energy. STM and STS are used to study the structure and electronic properties of the surface.

Surface Quasi-Particle Spectra – HREELS

High Resolution Electron Energy Loss Spectroscopy (HREELS) uses low energy monochromatic electrons to study the dielectric response of a surface through quasi-particle excitations. HREELS reveals metal-insulator transition is synchronized with phonon dynamics for $\text{Ca}_{2-x}\text{Sr}_x\text{RuO}_4$.

Surface Structure – LEED

Low Energy Electron Diffraction (LEED) reveals the surface structure of the crystals. By tracking diffraction spots as a function of incident electron beam energy (LEED-IV), surface reconstruction can be calculated to determine the rotation and tilt of the RuO$_2$ octahedra.

What We Have Found...So Far

$\text{Sr}_2\text{RuO}_4$

Bulk $\text{Sr}_2\text{RuO}_4$ has a bulk phonon which freezes into a structural distortion as temperature is lowered. Creation of surface freezes the soft phonon resulting in surface reconstruction with RuO$_2$ octahedra rotated by ~9° producing ferromagnetic ordering.

$\text{Ca}_{1.9}\text{Sr}_{0.1}\text{RuO}_4$

Doping creates an orthorhombic bulk structure altering the bandwidth and electron-electron (e-e) correlations resulting in Mott metal-insulator transition (MIT). Creation of a surface is expected to increase e-e correlations causing higher MIT transition temperature at the surface. However, surface reconstruction distorts the RuO$_2$ octahedra resulting in a LOWER transition temperature.

To Be Continued...