An Unusual Surface Mott Insulator-to-metal Transition (I)

Plummer, University of Tennessee, DMR-0072998

In 1929, Mott realized that the interactions between electrons can be responsible for the insulating character of a material. The Mott insulating phase is key in understanding transition-metal oxides, fullerene compounds, as well as organic conductors. Some of these materials are near an electronic instability, so it is possible to observe a Mott-insulator-to-metal transition. Such a transition dramatically alters the character of the electron. On the metallic side it is a delocalized state which conducts electricity. On the insulating side the electron is localized in space, bound to an individual atom or molecule. $Ca_{2-x}Sr_xRuO_4$ exhibits a Mott transition at 150 K for x=1.9.

Creating a surface breaks the symmetry, reduces the coordination and within conventional wisdom should localize electrons, raising the temperature of the Mott insulator-to-metal transition. We have used a multitude of experimental techniques to measure the temperature dependence of the geometric and electronic structure as well as the lattice dynamics. Surprisingly, as the figure shows the surface transition is at 130K, 20K lower than the bulk. This creates a very unique situation, a metal on top of a Mott Insulator.

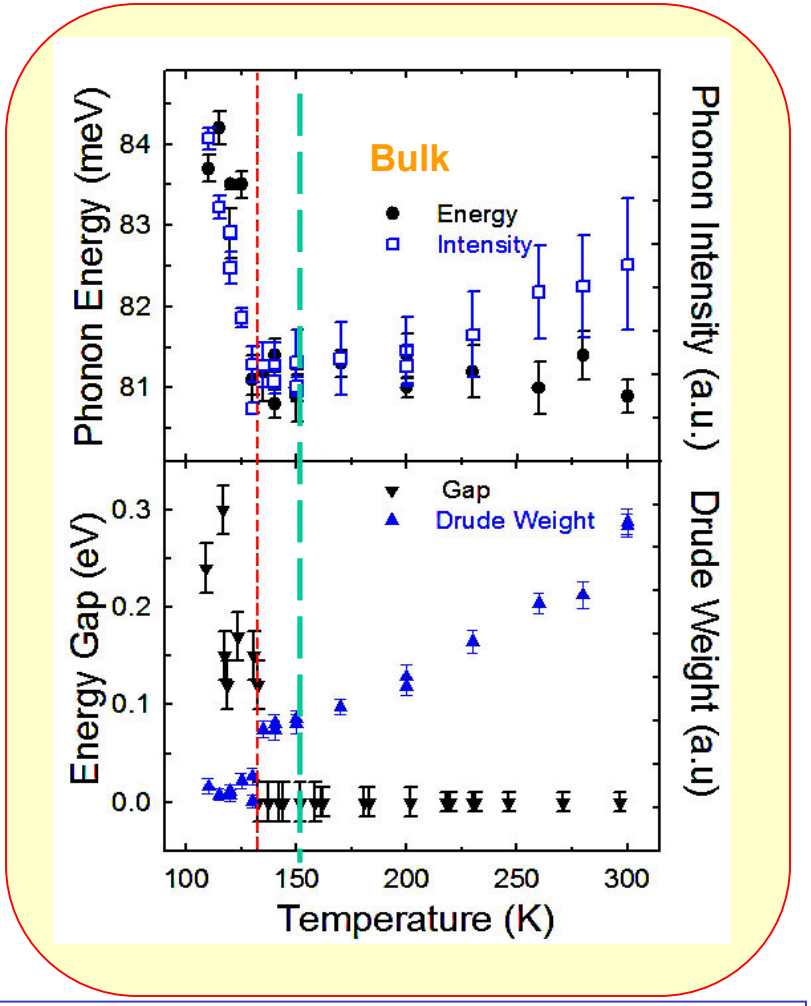

Fig. Caption: The top panel shows the intensity (right) and energy (left) of an optical phonon at the surface measured with Electron Loss Spectroscopy (ELS). The bottom panel displays the energy gap (left) determined with scanning tunneling spectroscopy and the Drude weight measured with ELS. The Drude weight is a measure of the conductivity of the surface. All four measurements give a transition temperature of 130K.

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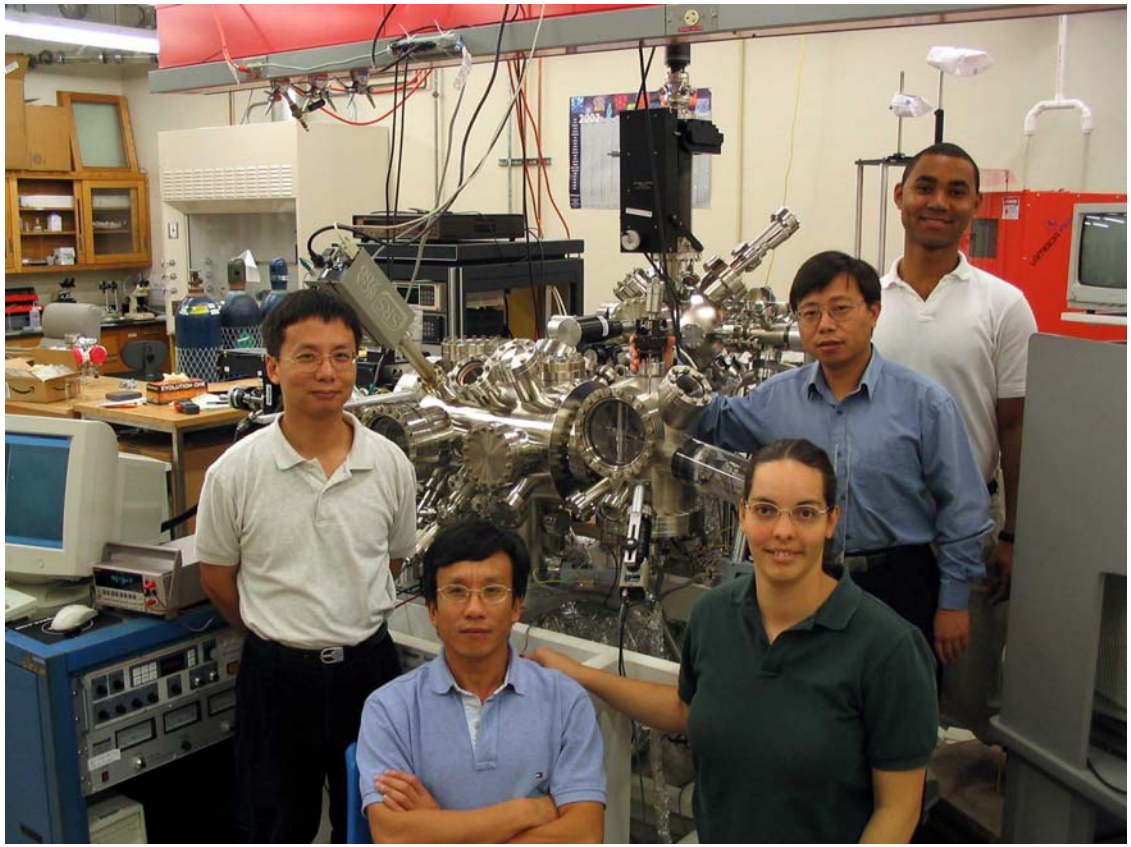
This project, is a partnership between the University of Tennessee (UT), Florida International University (FIU), and Oak Ridge National Laboratory (ORNL), which has allowed both graduate and undergraduate students to participate in advanced materials research using the most sophisticated instrumentation available, leading to careers in this technology-driven world.

The senior student at UT, Rob Moore, just won the outstanding poster award at the 2003 MRS meeting in Boston for this work.

Art Baddorf and Sergei Kalin (a Wigner Fellow) at ORNl have been instrumental in the utilization of Electron Loss Spectroscopy and David Mandrus and Rongying Jin (ORNL) have synthesized the samples used in these experiments.



The picture shows the group from FIU. Fernanda Foetter (front right), a Latina student, first became involved in this work in 2002 as an undergraduate at FIU. She is now a graduate student and her Ph.D. research will involves fabrication and characterization of artificially structured oxide materials. Stephane Stacco (left-back) is an Hispanic undergraduate student in Physics. Lei Cai (left) is a postdoc, and Chenxi Lu is a graduate student. Professor Zhang (front) teaches a Senior Physic Laboratory course to expose students to modern research techniques.