CORRELATED ELECTRON MATERIALS BY DESIGN

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SURFACE PHYSICS IN THE NEW MILLENNIUM

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Abstract

The April 2000 issue of Science featured the novel properties of "Electron Correlated Systems" [1]. In this presentation, I will talk about one family of highly correlated materials, Transition-Metal Oxides (TMOs). TMOs have attracted much attention in the materials community due to the richness and tunability of their novel properties. Specifically, these characteristics are believed to result from an astonishing variety of possible ground states very close in energy, so that the balance between competing phases is very subtle and small changes can create new phenomena. The best known examples of TMOs are the high temperature (high-T_C) superconductors and the colossal magnetoresistance (CMR) manganese oxides. Historically, the properties of these materials have been "tuned" by doping or changing the dimensionality. In this presentation, I will discuss the possibility to explore and exploit the collective phenomena exhibited by the TMOs by growing artificially-structured TMOs or creating surfaces or interfaces in which their exotic properties will respond to the broken symmetry present at a surface or interface and might be tuned by dimensional confinement, strain, or the interaction of the adjacent nanoscale entities. Conceptually, creating a surface is a controlled way to disturb the coupled system by breaking the symmetry. This unique environment could produce new phenomena, while providing a fresh approach to the study of the spin-charge-lattice coupling in these complex materials. I will present four examples to illustrate the unique properties of surfaces and interfaces of TMOs.

- The *p*-wave superconductor Sr_2RuO_4 is a layered TMO that can be easily cleaved in vacuum exposing large flat terraces of SrO termination. This surface reconstructs into a (2 2)R45° configuration which experiment and theory show is a consequence of the compressive strain in the RuO_2 plane, resulting in a rotation of the octahedra. The surface reconstruction freezes in a bulk-zone boundary soft phonon and theory predicts that this structure stabilizes the ferromagnetic (FM) fluctuations in the bulk creating a FM surface.
- The bulk phase diagram of $Ca_{2-x}Sr_xRuO_4$ contains rich and exotic behavior such as a *quantum critical point at* x~ 0.5 and a Mott insulator to metal transition at x<0.2. The surface Mott insulator to metal transition occurs at a lower temperature than the bulk, in conflict with simple physical arguments.
- Interfaces between two different TMOs can have very different properties compared to either of the building blocks. Recent experiments beautifully illustrate these phenomena. The interface between $CaMnO_3$ and $CaRuO_3$ exhibits FM-metallic behavior as a result of change in valence of the Mn and Ru atoms at the interfaces.
- The competition of variety of possible ground states very close in energy in TMOs leads to nanophase separation. I will discuss spatial inhomogeneities on the nanoscale in the high-T_C superconducting gap and the electronic gap in CMR materials.

This talk will end with a general philosophic discussion of Materials Research and Education in the New Millennium with a focus on the future of surface and interface physics.

1. Science, April 2000, Vol. 288, *Correlated Electron Systems*.
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