Nanoscale Electronic Transport Studies of Novel Strongly Correlated Materials

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Abstract
Strongly correlated materials are those in which the electron-electron and electron-lattice interactions play pivotal roles in determining many aspects of observable physical behavior, including the electronic and magnetic properties. In this thesis, I describe electronic

transport studies of novel strongly correlated materials at the nanoscale. After introducing some basic concepts, briefly reviewing historical development of the field, and discussing the process of making measurements on small length scales, I detail experimental results from studies of four specific materials: two transition metal oxide systems, and two layered transition metal dichalcogenides with intercalated magnetic moments. The first system is a modified version of a classic strongly correlated material, vanadium dioxide (VO2), which here is doped with hydrogen to suppress its metal-insulator transition and stabilize a poorly metallic phase down to liquid helium temperatures. Doped VO2 nanowires, micron flakes, and thin films display magnetoresistance (MR) consistent with weak localization physics, along with mesoscopic resistance fluctuations over short distances, raising questions about how to model transport in bad-metal correlated systems. A second transition metal oxide system is considered next: Quantum wells in SrTiO3 sandwiched between layers of SmTiO3, in which anomalous voltage fluctuation behavior is observed in etched nanostructures at low temperatures. After well-understood alternative origins are ruled out, an explanation is proposed involving a time-varying thermopower due to two-level fluctuations of etching-induced defects. Next, I shift to the topic of layered itinerant magnetic materials with intercalated moments, starting with Fe0.28TaS2, a hard ferromagnet (FM) with strong spin-orbit coupling. Here, a surprisingly large MR of nearly 70% is observed, an especially striking feature given that the closely related compounds at Fe intercalation fractions of 1/4 or 1/3 have MR nearly two orders of magnitude smaller. In the latter compounds, the Fe atoms are arranged in ordered superlattices, whereas for the 0.28 case, a portion of the Fe moments deviate from ordered arrangement and are relatively easily flipped by an external magnetic field to be anti-aligned with neighboring ordered Fe moments. This situation, combined with strong spin-orbit coupling, results in enhanced charge carrier scattering and greatly increased resistance. The thesis concludes with a study of a second layered magnetic material, V5S8 (structurally equivalent to V0.25VS2), which is found to have a magnetic field driven phase transition at low temperatures, believed to be from antiferromagnetism to paramagnetism. This transition is first order in thick crystals, but becomes second order as the crystal thickness decreases toward 10 nm. Together, the experiments described in this thesis highlight the complexity and diversity of strongly correlated materials, while showcasing the power of nanoscale electronic transport in delivering an improved understanding of these systems.

Keyword
Nanoscience; nanotechnology; nanoelectronics; transport measurement; vanadium dioxide;
More...

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