Size Dependence of Phase Transitions in Nanocrystalline Oxides

Richard Haglund, Leonard Feldman, Charles Lukehart (Vanderbilt), Michael Aziz (Harvard)

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Vanadium dioxide (VO_2), a semiconductor at room temperature, changes crystal structure and becomes metallic at 70˚C. Our first experiments on VO_2 nanocrystals showed that this transition temperature depends on size, leading to a size- and temperature-dependent electrical conductivity and near-infrared optical response. Moreover, the phase transition occurs in less than 10^{-13} seconds, as we showed by ultrafast white-light laser spectroscopy. To make nanoscale photonic or electronic device structures of VO_2 and similar oxides, we have developed ion-beam lithography into a robust technique for creating nanoscale patterned metal oxides. These could be used as building blocks for ultrafast optical switches or transistors.

Scanning electron micrograph of Picasso's drawing of "Don Quixote" in VO_2 (dark color) on an indium-tin-oxide waveguide. Smallest feature size is less than 50 nm.

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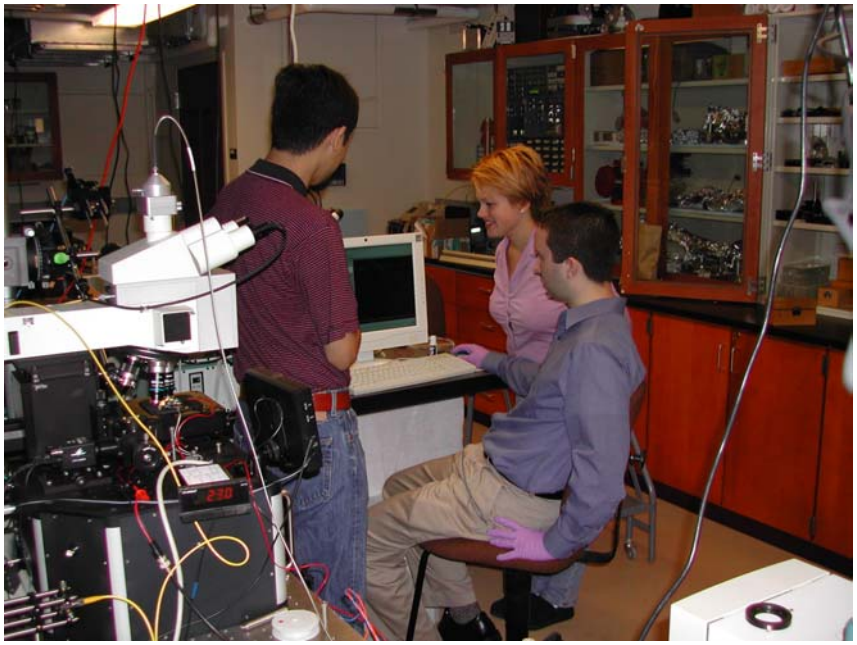
Education. This project integrates chemical and physical methods of nanoscale materials synthesis and characterization that cut across traditional intellectual boundaries. Graduate students Lisa Baker Sullivan (Chemistry) and Matthew McMahon (Physics), undergraduate Jonny Pellish (Physics) and postdoctoral scholar René Lopez have been engaged in cross-disciplinary learning through their research activities. The recently funded IGERT program linking Vanderbilt with Fisk University, an historically black college in Nashville, will bring a new group of students together for Vanderbilt's interdisciplinary nanomaterials science course in the fall of 2004, in which both phase transitions and scanning-probe microscopies will be part of the curriculum.



Graduate students Matthew McMahon and Lisa Sullivan (right) and postdoctoral scholar René Lopez discuss spectra of a single VO_2 nanoparticle made using the scanning near-field optical microscope.