Atomic scale characterization of functional oxide materials

The research in the Nano-Physics Group of Professor Robert F Klie is centered around the atomic-scale characterization of functional oxide materials using high-resolution Z-contrast imaging[21-22] and electron energy-loss spectroscopy (EELS)[23] in the transmission electron microscope (TEM). The research is being performed using the state-of-the-art TEM facilities in the Research Resources Center (RRC) at UIC, which include the JEOL 2010F, in 1998 this was the highest resolution TEM/STEM anywhere in the world,[24] as well as the aberration-corrected VG HB601-UX, one of only 3 instruments in the world that can achieve sub-Å spatial resolution while providing a 0.3 eV energy-resolution for single-atom-sensitivity EELS.[25] This means that by combining the chemically-sensitive Z-contrast imaging method with single-atom-sensitivity EELS, not only can the atomic structure of an interface or an individual defect be directly imaged, but further the density of states, transition metal valence and the local magnetic moments of the material can now be measure with atomic-column resolution.

Professor Klie combines these high-resolution STEM techniques with in-situ heating and cooling specimen holders that allow for atomic-resolution imaging in the temperature regime between 10 K and 1000 K. In 2000, he was the first to report atomic-resolution imaging and spectroscopy in a STEM at 724 K[26-27] and only recently he has shown that high-resolution TEM imaging and spectroscopy can be achieved at temperature as low as 10.4 K.[28] Therefore, the phase transitions, defect diffusion and dynamics in many functional oxide materials can now be studied on the atomic scale. In particular, the role of grain boundaries in high-temperature superconductors,[29] the effects of defects and interfaces in oxide thermoelectric, magneto-resistive materials and high-k dielectrics, and the role of the metal-support interaction in heterogeneous catalysts systems are being studied by atomic-resolution Z-contrast imaging and EELS. Specific tasks of the REU fellows include the use of TEM and STEM/EELS in order to develop a fundamental understanding of the structure-properties relation ships in these functional oxide materials that find applications in areas ranging from heterogeneous catalysis, to semiconductor devices, spintronics and superconductivity.

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