NEAT ORU
Nanomaterials in the Environment, Agriculture and Technology
Organized Research Unit
UC DAVIS
Summer 2005

NEAT HIGHLIGHTS

High-Resolution Transmission Electron Microscope JEOL JEM-2500SE

High-resolution transmission electron microscopy (HR-TEM), as well as high-resolution transmission electron microscopy (HR-STEM) in combination with the extensive analytical capabilities, has proved invaluable for nanoscience and technology. To draw full benefits of these unique techniques a 200kV field emission JEOL JEM-2500SE is presently built-up in the Microscopy Central Facilities of the Chemical Engineering and Materials Science Department at UC Davis. This instrument displays a variety of atomic resolution images: TEM-, STEM- (spatial resolution of ~0.2 nm), secondary electron images, diffraction pattern and has full analytical performance with high-sensitivity energy dispersive X-ray spectrometer (EDS) and high-resolution electron energy-loss spectrometer (EELS), all with atomic resolution and sensitivity, which makes this instrument essential for nanomaterials researchers at UC Davis. The above average pole-size gap of this microscope facilitates the application of tomography, and in-situ stages. Electron tomography is a novel technique to determine the shapes and 3-D arrangements of nanoparticles. In-situ stages allow the dynamics of nanoscale systems to be studied under various conditions of temperature, gas pressure, strain and applied voltage. Initially, an environmental heating-stage will be developed with differential pumping apertures that permit a small gas pressure to be maintained around the sample, allowing the exploration of structure-property relationships under conditions closer to the true operating environment.

Fig 1, Present state of microscope installation

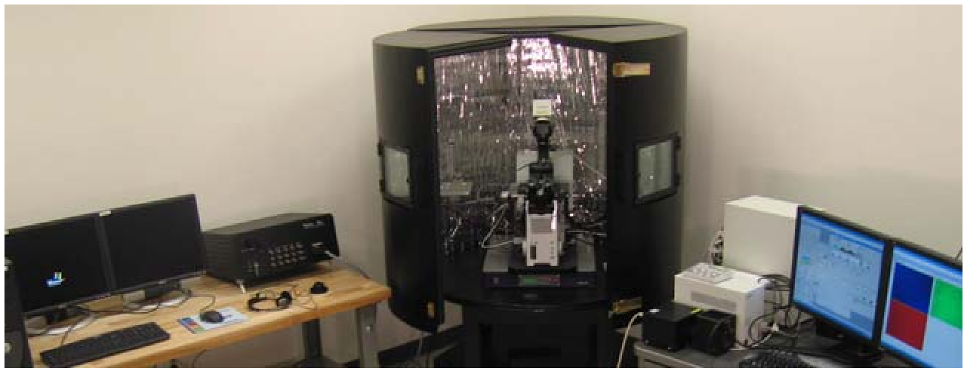
Fig. 1 shows the present state of the microscope installation. The field emission gun is attached, the 200 kV high-tension runs stable, the microscope is already equipped with the Gatan Energy filter and the EDX system will be installed pretty soon. As it is common for such state of the art instrumentation, the alignment and resolution tests will take a couple of weeks, so the "grand opening" can be scheduled for the beginning of June. Fig 2 shows the final state of JEM 2500SE. The advanced computer control of the microscope means that both undergraduate and graduate students can perform atomic scale analysis under the close supervision of a teacher and with no possibilities of damaging the instrument, and is therefore suited for both novice and experts. The flexibility and widespread usability is key to success of this instrument and will perform research at the highest level.

Fig 2, Final state of the JEM 2500SE

The National Science Foundation provided funding for instrumentation acquisition under NSF-MRI program, DMR-0321356, co-PIs include Dr. Alexandra Navrotsky and Dr. Valerie Leppert. NEAT-ORU and the University provided additional funding and support.

The CCOAFM Facility Opening Planned for September 2005

The Chemistry Department has designated Chemistry Laboratory 11, previously occupied by a General Chemistry lab, as the new home for the high-resolution laser scanning inverted Combined Confocal Optical Atomic Force Microscope (CCOAFM) NEAT ORU shared use facility on the UC Davis campus. The basement location was chosen specifically for the low vibration environment required by the ultra-sensitive CCOAFM imaging system. Additional quiet laboratory features will include a half-ton isolation chamber, in which the CCOAFM will be positioned, on a vibration-dampening floor mounting system. To further reduce airborne vibrations and particulates, laminar flow, HEPA filtered heat/cool air supply registers mounted in a gasketed drop ceiling will be used throughout the 1000 square foot facility. Users will be asked to follow minimal clean room protocols to reduce particulate contamination in the lab. Considerable effort has gone into planning for lab renovations, which will be completed by late July 2005. The instruments are scheduled for installation and testing shortly thereafter. The tentative opening date to the research community is set for mid-September 2005.



Campus researchers will have access to one of the first combined confocal AFM laboratory instruments. Each of these microscope methodologies is extremely useful in observing characteristics of biological and material samples on the microscopic scale and below. Laser scanning confocal microscopy provides image capture of dynamic processes at the cellular and sub-cellular levels in a three-dimensional realm on the micro-scale, where atomic force microscopy provides images at the boundaries and surfaces on the nano-scale. Until now, configuration and size limitations have prevented mounting an AFM scanning head to a confocal microscope stage. With the advent of the Asylum Instruments MFP-3D, researchers will be able to optically observe surfaces and interfaces of interest at the micrometer level and simultaneously analyze them at the nanometer level.

With confocal microscopy, in comparison to conventional microscopy, it is possible to image a specimen in three-dimensions by excluding stray light through an extended depth of focus. In principle, a pinhole aperture on a conjugate focal plane of the sample eliminates out of focus light above and below the point of focus in the sample. The pinhole and the focal point in the specimen are thus confocal. As the focused excitation from a laser source is scanned across the specimen, the resulting spectral emissions from fluorochromes and other fluorescing substances are detected, resulting in a cross-sectional colored image of the sample. The scanned discrete x-y image planes are stacked to create a volume with depth detail for the sample. In this way the three-dimensional spatial structure of the sample is revealed, showing complex interrelationships. The spectral emission detector in the Olympus FV1000 has a 2 nm resolution allowing fluorochromes with similar but distinct emission profiles to be separated.

Atomic force microscopy uses an ultra sharp stylus perpendicular to the end of a chemically milled silicon beam, or cantilever, as a probe in contact or near contact with the sample surface of interest. As the cantilever is moved across the sample, a narrow beam of light is focused on and reflected off the backside of the cantilever. It is the subtle, minute motions of the reflected light beam off the cantilever that allow the features of the sample to be resolved down to the sub-nanometer scale. The sample is mounted on a piezoelectric actuator stage, which can move in the z, x, and y directions. The small-scale motions of the reflected light are used to generate a very precise, low noise electronic error signal from the cantilever position sensor that is used to manipulate the sample stage such that the cantilever is never deflected beyond its linear range or its breaking limit. The piezoelectric actuator stage has a relatively small range of motion, on the order of 10s of micrometers, so the AFM scanning stage must move within sub-millimeter bounds with nanometer precision. As the scanning stage is moved along the X and Y-axes the electronic error signal represents the nanoscale features of the sample and is used to generate an image. The Asylum MFP-3D scanning head incorporates a new design which uses separate piezoelectric actuators in conjunction with 110KHz LVDT magnetic position sensors in X, Y and Z, to ensure accurate positioning and fast scan speeds.

The National Science Foundation has provided funding for instrumentation acquisition under NSF-MRI program, DMR-0421521, co-PIs include Dr.Gang-yu Liu, Chemistry, Dr. Yin Yeh, Applied Science, Dr. Atul Parikh, Applied Science, and Dr. Don Land, Chemistry. NEAT ORU, Chemistry Dept., Applied Science Dept., College of Math & Physical Science, the College of Engineering, and the Office of Research provided additional funding towards the acquisition and operations of this facility.

Details regarding the hourly recharge, training, and utilization of the facility are pending final approval by NEAT ORU, Chemistry, and the University.

Recruitments On-going for Two Tenured Faculty Positions in Nanoscale Biological Physics and Chemistry.

UC Davis invited applications for two faculty positions in nanobioscience, one a joint appointment in the Division of Biological Sciences and the Physics Department, and the other in the Department of Molecular and Cellular Biology and the Chemistry Department. These tenured positions are part of the interdisciplinary program in Nanomaterials in the Environment, Agriculture, and Technology (NEAT). Preferred candidates will develop strong research programs at the interface between biological and physical sciences, using methods of nanotechnology for the study or manipulation of biological macromolecules at the nanoscale to contribute to the advancement and understanding in frontier biological science, or taking advantage of bioscience concepts for the development of the next generation of nanomaterials. The interplay between nanoscale materials science and biological phenomena is one of the most promising avenues for major scientific discoveries and technologies (nanoscale mechanical and electronic devices, sensors, medical diagnostic tools, biomimetics, etc.). These searches are now in their final stages.

Student Testimonial ~

On Multidisciplinary/Interdisciplinary Training Activities Fostered or Funded by the IGERT Project.

It is plain and simple: the reason my current project came to fruition is due to the NEAT/IGERT programs success in exposing me to interdisciplinary research. My research, the investigation of human eye lens physiology as it pertains to cataract formation, combines elements of ophthalmology, physiology, biochemistry, and accelerated mass spectrometry. Furthermore, the NEAT/IGERT initiative has enabled me to take additional coursework that has proven to be absolutely invaluable in getting where I am today; courses in such topics as ethics, public speaking, media relations, and grant/proposal writing. All of these factors, plus the professional network I am continually establishing through the process, have enabled to me to generate research that would not have been possible without the program.

Daniel Stewart
Ph.D. Candidate
Department of Chemistry

NEAT IGERT GRADUATES 2004 – 2005

Student	Professor	Department	Where are they now?
Ram Allada	Alexandra Navrotsky	Thermochemistry Facility	Post Doc NASA Johnson Space Center
Javier Guzman	Bruce Gates	Chemical Engineering	Faculty University of Kansas
Eric Moloy	Alexandra Navrotsky	Thermochemistry Facility	Research Scientist, Intel
Katharine Pettigrew	Susan Kauzlarich	Chemistry	Post Doc Naval Research Laboratory

Professor Charles Fadley Receives Career Award

Prof. Charles Fadley, UCD Physics Department, has won the Medard W. Welch Award from the AVS (American Vacuum Society). He is being recognized "For the development of novel techniques based on photoelectron spectroscopy and synchrotron radiation, and their application to the study of the atomic, electronic, and magnetic structure of surfaces and buried interfaces, and for the mentoring of young scientists." This is a major award in the field of surface physics and chemistry. The purpose of the award is "To recognize and encourage outstanding research in the fields of interest to the AVS." The AVS website says, "The award consists of a $10,000 cash award, a struck gold medal and a certificate setting forth the reasons for the award, and an honorary lectureship at a regular session of the International Symposium." Professor Fadley's graduate student, Brian Sell, was a NEAT-IGERT fellow and received funding from the National Science Foundation during his first two years of study.

Professor Alexandra Navrotsky Receives Awards

Spriggs Phase Equilibria Award

The American Ceramic Society (ACS) Board of Directors unanimously bestowed upon Professor Navrotsky and Professor Masao Morishita (Himeji Institute of Technology) the honor of the Spriggs Phase Equilibria for their paper 'Calorimetric Study of Nickel Molybdate: Heat Capacity, Enthalpy, and Gibbs Energy of Formation,' J. Am. Ceram. Society, 86[11]1927-32(2003). The award was presented during the American Ceramic Society's 107th Annual Meeting, April 12, 2005 in Baltimore, Maryland.

Urey Medal

The Urey medal is the highest award of the European Association of Geochemistry (EAG) and honors outstanding senior scientists for their life-long contributions to geochemistry. The award was presented to Dr. Navrotsky at this year's Goldschmidt Conference held in Moscow, Idaho in May 2005.

NEAT ORU Advisory Board

Vice Chancellor Barry Klein recently appointed an advisory committee to help frame the future of the NEAT ORU and will be critical to evaluating its effectiveness on a continuing basis. Members will serve a three-year appointment with the inaugural meeting scheduled for Friday, January 20, 2006. Members include: Louise Kellogg (chair), Physics; Ian Kennedy, Mechanical & Aeronautical Engineering; Gang-yu Liu, Chemistry; Warren Pickett, Physics; Sabyasachi Sen, Chemical Engineering & Materials Science; Ram Seshadri, Materials Department, UCSB; Sarah Tolbert, Chemistry & Biochemistry, UCLA; and James De Yoreo, Biosecurity & Nanoscience Laboratory, LLNL.

New NEAT Grants & Contracts

Professor Gang-yu Liu

- $354,000 from National Science Foundation, "Acquisition of a Combined Confocal Optical and Atomic Force Microscope"

Professor Alexandra Navrotsky

- $153,357 from Sandia National Laboratory, Research Agreement "Synthesis and Characterization of Tunable Perovskite Ceramics"
- 517,264 from Department of Energy, "Energetics of Nanomaterials"
- $360,000 from National Science Foundation, "US-German Materials Collaboration: Unusual Stability of Amorphous Polymer Derived Ceramics at High Temperatures"
- $30,000 from Department of Energy, "Energetics of Cancrinite"
- $24,253 from BHP Billiton (Australia), Research Agreement "Melt Formation and Crystallization"
- $385,404 from Argonne National Laboratory, Research Agreement "Direct Determination of the Thermodynamic Properties of Uranyl Minerals at Yucca Mountain"