Research Activity: Electron-beam Microcharacterization

Division: Scientific User Facilities
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Portfolio Description:

This activity supports three electron-beam microcharacterization user centers: the Electron Microscopy Center for Materials Research (EMC) at Argonne National Laboratory (ANL); the National Center for Electron Microscopy (NCEM) at Lawrence Berkeley National Laboratory (LBNL); and the Shared Research Equipment Program (SHaRE) at Oak Ridge National Laboratory (ORNL). These centers contain a variety of highly specialized instruments to provide information on the structure, chemical composition, and properties of materials from the atomic level on up, using direct imaging, diffraction, spectroscopy, and other techniques based primarily on electron scattering. They accommodate over 500 users annually and also participate in leading-edge instrument development. These three facilities, along with two other BES-funded efforts, collaborate on the Transmission Electron Aberration-corrected Microscope major item of equipment project to develop a next-generation platform for electron microscopy and an initial instrument optimized for high resolution and atomic tomography.

Unique Aspects:

Electron probes are ideal for investigating local structure and chemistry in materials because of their strong interactions with atomic nuclei and bound electrons, allowing signal collection from small numbers of atoms–or, in certain cases, just one. Furthermore, the use of these charged particles allows electromagnetic control and lensing of electron beams resulting in spatial resolution that can approach single atomic separations or better (i.e., approaching or exceeding 0.1 nm). The BES electron-beam characterization user facilities provide unparalleled access to specialized equipment and expert staff and develop next-generation instrumentation and characterization techniques. They make these capabilities available to the scientific community on the basis of submitted proposals and at no cost to non-proprietary users, and are the only facilities of this type focused on electron-beam characterization that are available in the nation.

Relationship to Others:

These activities couple with many others in BES programs and enable a broad range of research across numerous fields, including physics, chemistry, and materials science, within national laboratory programs as well as for academic and other scientists. The most direct relationship is with the Structure and Composition of Materials program, of which this was a part prior to FY 2007. There are also strong interactions with other BES user facilities, particularly with the collocated Nanoscale Science Research Centers. The electron-beam centers support use by researchers funded by BES, by other parts of the Office of Science, by other parts of the Department of Energy, and by numerous other federal agencies.

Significant Accomplishments:

Major historical accomplishments for the electron-beam characterization centers have included the development and operation of the Atomic Resolution Microscope (in the early 1980s) and One-Angstrom Microscope (in the late 1990s) at NCEM, which have been world-leading instruments in demonstrated lateral spatial resolution. Extensive in-situ work on radiation damage in materials has been done in unique facilities at EMC, which has operated several TEMs attached directly to ion accelerators. The SHaRE program has emphasized chemical identification and spectroscopy, with notable achievements in pinpointing the elemental segregation phenomena leading to brittleness or toughening behavior at ceramic interfaces and in developing and using novel methods and tools such as atom location by channeling-enhanced microanalysis (ALCHEMI) and the local electrode atom probe (LEAP). Recent scientific advances have included measurement of picometer-level atomic displacements, structural determination of nanoscale particles and novel defect structures such as "chevron" features at grain boundaries, and application of microcalorimetry to vastly improve energy resolution in localized analysis within multiphase superalloys and interplanetary dust particles.

Mission Relevance:

Atomic arrangements, local bonding, defects, interfaces and boundaries, chemical segregation and gradients, phase separation, and surface phenomena are all aspects of the nanoscale and atomic structure of materials, which ultimately control the mechanical, thermal, electrical, optical, magnetic, and many other properties and behaviors.

Understanding and control of materials at this level is critical to developing materials for and understanding principles of photovoltaic energy conversion; hydrogen production, storage, and utilization; catalysis; corrosion; response of materials in high-temperature, radioactive, or other extreme environments; and many other situations that have direct bearing on energy, environmental, and security issues.

Scientific Challenges:

One of the current major challenges in electron beam techniques is to take the greatest possible advantage of recently-demonstrated (and still developing) capabilities for correcting the aberrations of electron microscope lenses. The opportunities includes improvement of spatial resolution, but also offer the promise of much more extensive in-situ and other capabilities as a result of increased flexibility and space in the sample stage and surrounding area. The TEAM project that the three electron-beam centers participate in is a major effort to address these prospects. Also, with extensive work already underway in nanoscience and the transition to operations of the DOE collocated Nanoscale Science Research Centers, the electron-beam facilities provide unique opportunities to interrogate local structure and chemistry at individual nanoscale features, and will be challenged to address a large variety and volume of scientific issues across the broad spectrum of this field.

Funding Summary:

Dollars in Thousands

FY 2005	FY 2006	FY 2007 Request
7,614	7,945	7,945

Projected Program Evolution:

The electron-beam characterization facilities were previously supported within BES research programs and in FY 2007 come under the category of scientific user facilities, with corresponding formal responsibilities for both scientific excellence and user productivity and satisfaction. Further development will be driven by the scientific needs of users and will involve suitable renewal of instrumentation and a continued increase in interactions with other BES user facilities.