The Advanced Photon Source

HEDM at APS Sector 1

The strategic development of new engineering materials with improved performance rests on establishing computational models that link materials processing, microstructure, properties, and performance. Scientists and engineers have long sought these linkages, but without access to experimental data at the relevant length scales, validated models capable of predicting complex phenomena such as fatigue crack initiation and deformation in polycrystals have remained elusive. Developing such models is at the heart of integrated computational materials science efforts as well as the recently launched Materials Genome Initiative.

The use of experimental methods capable of validating materials models over the appropriate processing or service conditions — i.e., length/time scales, and deformation/temperature regimes — are essential to these efforts. The development of cutting-edge characterization techniques capable of exploring the links between processing, microstructure, and properties/performance has been accelerated by coordinated efforts at high-energy synchrotron x-ray beamlines. Over the past decade, this has led to the development of high-energy diffraction microscopy (HEDM, also known as 3DXRD) at the Advanced Photon Source (APS) (beamline 1-ID); the European Synchrotron Radiation Facility in France (beamline ID11); and, more recently, the Deutsches Elektronen-Synchrotron (DESY)/PETRA in Germany and the Cornell High Energy Synchrotron Source facilities. The result of these efforts is a suite of nondestructive techniques to characterize and monitor evolving material states, including sub-grain orientations, void/crack formation, and the stress states of individual grains.

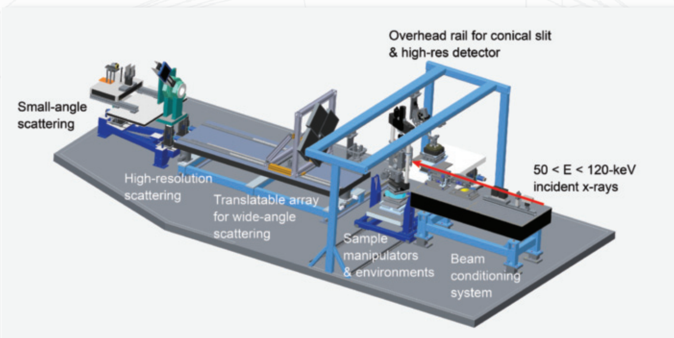

Fig. 1. 1-ID-E hutch at the APS constructed for high-energy diffraction microscopy measurements, with beam shown incident on a vacuum furnace used for thermo-mechanical studies of irradiated materials and key components labeled.

At the APS, the recently built E-hutch at beamline 1-ID-E houses near- and far-field HEDM, tomography, and small-angle x-ray scattering (SAXS) capabilities (Fig. 1). The beamline is fed by a high-energy undulator, a brilliance-preserving monochromator, and refractive focusing lenses to provide a high flux of 50 < E < 120-keV x-rays with beam sizes down to a micron. Specialized user environments, developed through collaborations with external partners including the Air Force Research Laboratory, allow high precision *in situ* measurements of samples undergoing a variety of mechanical loading conditions at ambient and high temperatures; a vacuum furnace enables *in situ* thermo-mechanical measurements on irradiated materials. A variety of specialized area detectors are available, including high-spatial-resolution "near-field" diffraction/ tomography systems, an array of flat-panel detectors for "far-field" diffraction, and a SAXS detector with medium-resolution placed at the back of the hutch.

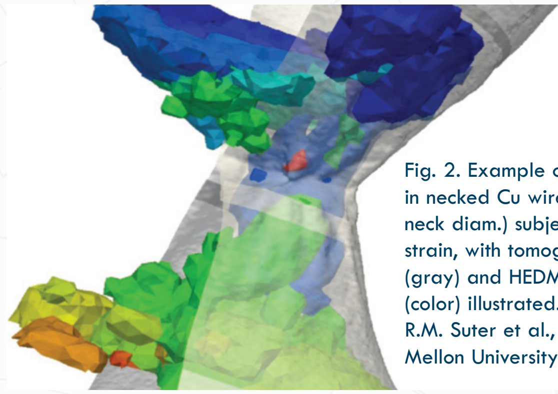

Fig. 2. Example of HEDM data in necked Cu wire (250-μm neck diam.) subjected to tensile strain, with tomography contour (gray) and HEDM grain mesh (color) illustrated. (Courtesy of R.M. Suter et al., Carnegie Mellon University)

HEDM datasets are inherently multi-dimensional (three-dimensional space and orientation, six-dimensional strain tensor, several time/processing steps), which results in large data volumes and the need for correlated data analysis. For example, HEDM grain maps, such as that shown in Fig. 2, require ~30,000 area detector images with each image being roughly 8 MB in size, or 240 GB for this particular *in situ* loading condition; several load steps are desired to observe material evolution. Algorithms are in active development to reduce, analyze, image, and fuse these large, high-dimensionality data sets using cluster and supercomputing resources.

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Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the facility's high-brightness hard x-ray beams.

General-user proposals for beam time during Run 2014-3 are due by Friday, July 11, 2014.

Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

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