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Mesoscale Science with High Energy X-ray Diffraction Microscopy at the Advanced Photon Source[1]

ROBERT SUTER, Carnegie Mellon University

Spatially resolved diffraction of monochromatic high energy (> 50 keV) x-rays is used to map microstructural quantities inside of bulk polycrystalline materials. The non-destructive nature of High Energy Diffraction Microscopy (HEDM) measurements allows tracking of responses as samples undergo thermo-mechanical or other treatments. Volumes of the order of a cubic millimeter are probed with micron scale spatial resolution. Data sets allow direct comparisons to computational models of responses that frequently involve long-ranged, multi-grain interactions; such direct comparisons have only become possible with the development of HEDM and other high energy x-ray methods. Near-field measurements map the crystallographic orientation field within and between grains using a computational reconstruction method that simulates the experimental geometry and matches orientations in micron sized volume elements to experimental data containing projected grain images in large numbers of Bragg peaks. Far-field measurements yield elastic strain tensors through indexing schemes that sort observed diffraction peaks into sets associated with individual crystals and detect small radial motions in large numbers of such peaks. Combined measurements, facilitated by a new end station hutch at Advanced Photon Source beamline 1-ID, are mutually beneficial and result in accelerated data reduction. Further, absorption tomography yields density contrast that locates secondary phases, void clusters, and cracks, and tracks sample shape during deformation. A collaboration led by the Air Force Research Laboratory and including the Advanced Photon Source, Lawrence Livermore National Laboratory, Carnegie Mellon University, Petra-III, and Cornell University and CHESS is developing software and hardware for combined measurements. Examples of these capabilities include tracking of grain boundary migrations during thermal annealing, tensile deformation of zirconium, and combined measurements of nickel superalloys and a titanium alloy under tensile forces.

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