Submicron Resolution, 3D X-Ray Structural Microscopy for Fundamental Studies of Plastic and Elastic Deformation*

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The availability of high-brilliance synchrotron x-ray sources and new, high-precision x-ray focusing optics have made possible revolutionary advances in microbeam x-ray capabilities for the investigation of materials microstructure on mesoscopic length scales of tenths-of-microns to hundreds-of-microns. Exploiting these capabilities, we have developed a new and powerful technique for submicron resolution 3D x-ray structural microscopy. Differential-aperture (knife-edge) profiling of Laue diffraction patterns from white x-ray microbeams makes it possible to extract full diffraction patterns from submicron voxels (volume elements) in bulk materials. For the first time, nondestructive measurements of the local crystallographic orientation, structural phase, morphology, and full stress/strain tensor can be performed in single-crystals, polycrystals, composites, multilayers, and deformed materials.

The technique for differential-aperture x-ray microscopy (DAXM) with submicron point-to-point spatial resolution in three-dimensions will be presented and the following applications of the method will be discussed:

(1) Micron resolution measurements of the local structure, orientation, and grain size in hot-rolled aluminum,
(2) Micron resolution measurements of the local orientation and elastic strain tensor as a function of depth in cylindrically bent silicon,
(3) Micron resolution measurements of plastic strain and the geometrically necessary dislocation (GND) densities in single-crystal regions and near a grain-boundary in a plane-strained aluminum tri-crystal, and
(4) Micron resolution measurements of the plastic strain and GND distributions under a nanoindent in single-crystal copper.

These newly developed measurement capabilities provide a direct – and previously missing – link between the actual microstructure and evolution in materials on mesoscopic length scales and the results of theory, simulation, and modeling of materials processes.

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