Three Dimensional Deformation Microstructure Measurement Under Indents Using Submicron Resolution X-Ray Structural Microscopy

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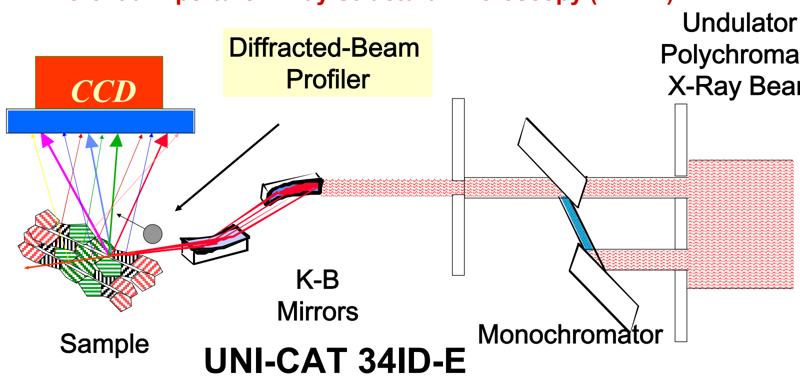
- Materials properties depend largely on mesoscopic structure and evolution on length scales from tenths of microns to hundreds of microns
- Nondestructive, in-situ measurements provide a direct link to theory, simulations, and multi-scale modeling of structural evolution
- 3D X-Ray Structural Microscopy provides point-to-point full diffraction information from submicron volume elements
- The entire volume of deformed materials under microindents is possible to be measured with x-ray microdiffraction technique
- 3D measurements of local lattice rotation and dislocation patterning under indents provides a direct comparison with theory and computer modeling under known boundary conditions

Experimental setup

3D Depth resolved Laue diffraction technique

Differential-Aperture X-Ray Structural Microscopy (DAXM)



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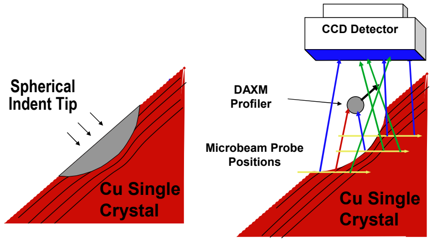
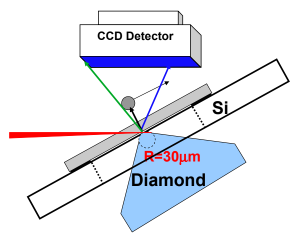
- Depth resolved diffraction technique provides full diffraction information from each length segment along the beam
- Local lattice rotation and lattice strain can be mapped in 3D with micron resolution
- Geometrically necessary dislocation (GND) tensor and density can be obtained with micron resolution
- Investigation of microtexture and grain structure evolution

Indentation Probe Geometry



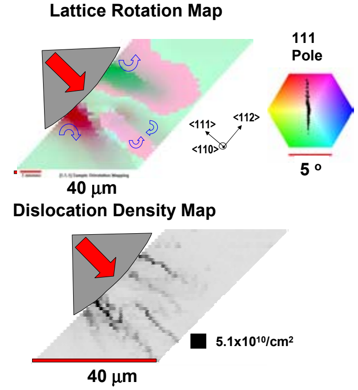
Ex-situ



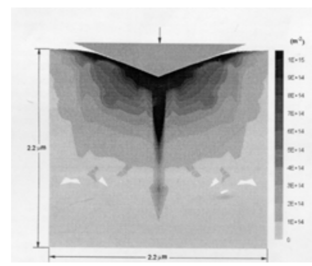
In-situ

Results and comparison

100 mN Spherical Indent

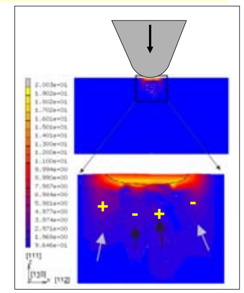


Finite Element Simulations



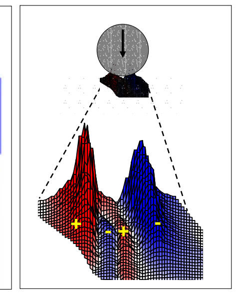
GND density under a conical indent in polycrystal Cu calculated using strain gradient plasticity

Huang et al. J. Mater. Res., 15(2000),1786



Crystal-plasticity simulation of the misorientation field under the rounded point of a conical indenter in Cu

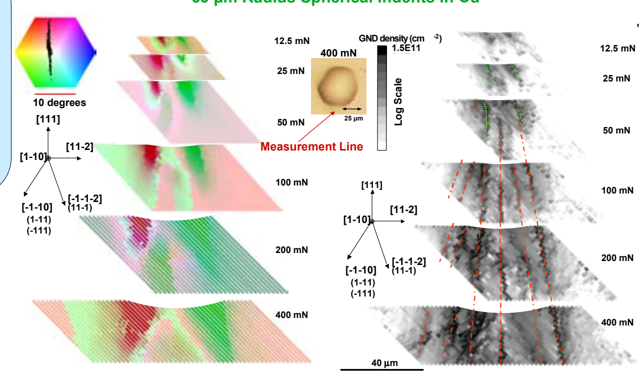
[Wang, Raabe, Kluber and Roters 2004 Acta Mater 52, 2229]



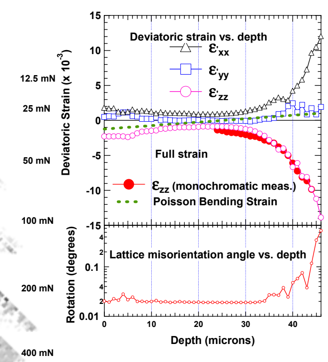
DAXM measurement of misorientation field under a spherical indent in Cu

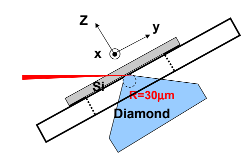
Evolution of lattice rotation and GND density

Orientation and GND Density Mapping Below 69 μm Radius Spherical Indents in Cu



In situ measurements of lattice rotation and elastic strain induced in Si by a 30 μm radius spherical indenter (400 mN)





Near indent tip
- Lattice rotation ~ 8°
- Surface normal strain ε'_{zz} up to -1.5%
- $\varepsilon'_{zz} \cong - \varepsilon'_{xx}$

3D, nondestructive measurements of deformation microstructure are possible with submicron spatial resolution. Lattice rotations have been measured with micron resolution in spherical indented Cu. Both elastic strain and lattice rotation have been measured with micron resolution during in-situ spherical indentation of Si.

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