

Electron Tomography and Electron Holography of Dislocations

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The study of dislocations using experimental and theoretical methods is important for understanding deformation mechanisms in materials. However, the three-dimensional characterization of dislocations with nanometer spatial resolution using electron tomography [1, 2] remains a challenge, especially at grain boundaries. Here, using an FEI Titan microscope with a C_s probe corrector operated at 300 kV, we acquire experimental tilt series of annular dark field (ADF) (Fig. 1), bright field and conventional dark field images and use image analysis and tomographic reconstruction to characterize the dislocation structure in deformed aluminum in three dimensions. Fig. 1 shows ADF images of deformed aluminum at several tilt angles acquired from a region with an average thickness of approximately 80 nm. The images were acquired using a standard single tilt tomographic holder. A region of the specimen that was found to be oriented close to a two beam condition with $g=\{200\}$ at 0° tilt angle (Fig. 1c) was chosen for electron tomography. At this orientation, two third of dislocations with Burgers vector of type $\frac{1}{2}\langle 110 \rangle$ are visible and these dislocations exhibited narrow well-defined contrast. As the specimen tilt angle was varied, changes in diffraction condition and specimen height might result in blurring of the dislocations. In order to investigate this blurring, a series of ADF images was acquired over a range of defocus values from -500 to +500 nm with a step size of 50 nm. The blurring was observed to remain constant with image defocus and varied only with specimen tilt angle, i.e., with diffraction conditions. We discuss the specimen geometry, imaging conditions and processing steps that are required for accurate tomographic reconstruction. We also use off-axis electron holography to acquire phase images of dislocations in aluminum in a variety of diffraction conditions. Experimental electron-optical phase images are compared quantitatively with simulations, in part to investigate whether they can provide information about dislocations that are not visible using conventional diffraction contrast techniques.

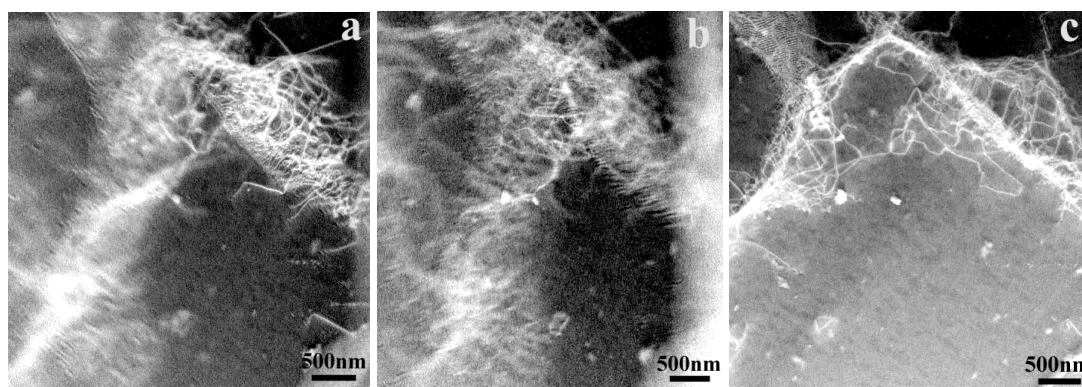


Fig.1. Annular dark field images of a dislocation entanglement close to a grain boundary in deformed aluminum, acquired at specimen tilt angles of a) -50° , b) $+50^\circ$ and c) 0° .

References

- [1] J.S. Barnard et al., *Science* 313 (2006), 319.
- [2] M. Tanaka et al., *Scripta Materialia* 59 (2008) 901.