Quantitative study of plastic deformation in aluminum using EBSD, TKD, and PED-based orientation imaging techniques

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Diffraction analytical techniques, such as electron backscatter diffraction (EBSD), transmission Kikuchi diffraction (TKD), and precession electron diffraction-assisted automated crystal orientation mapping (PED ACOM), are commonly used for studying deformation. The techniques are complementary; EBSD can gather data from a very large area, but has limited resolution; TKD offers higher resolution than EBSD with a relatively large area of mapping; and TEM offers the highest resolution analysis of a local area. Materials deformation studies that use these techniques are based on small, local, crystal orientation changes that must be measured with high accuracy. Sample preparation strongly affects the accuracy and precision attained in strain analyses. For example, an EBSD signal comes from the top 30 to 50 nm of a sample; therefore, the sample requires high-quality surface preparation. TKD and TEM orientation imaging require an electron transparent sample. Both bulk and electron transparent samples must be free from contamination, crystal lattice damage, or plastic deformation. This study presents pure aluminum samples that were deformed under uniaxial compression at room temperature to obtain plastic strains of 0, 4, 6, and 15%. As a quantitative factor of deformation, we used kernel average misorientation KAM and geometrically necessary dislocations density ρ_{GND}, which can be derived from local orientation measurements if the elastic stress is neglected. We used two methods for determine GND density from orientation maps: ρ_{GND} is derived from dislocation density tensor; and ρ_{GND} is calculated from representations of low angle boundaries.

Four groups of samples were prepared:

- Group 1: Bulk samples prepared by conventional mechanical polishing (MP) using colloidal silica.
- Group 2: A subset of group 1 was further prepared by Ar broad ion beam (BIB) milling.
- Group 3: Electron-transparent lamellas were lifted from a subset of group 2 using Ga focus ion beam (FIB) and thinned by Ar narrow ion beam milling.
- Group 4: 3 mm disk conventional TEM samples were prepared using MP, followed by BIB.

Figure 1 to 4 demonstrate the effects of sample preparation in the KAM and ρ_{GND} measurements obtained by EBSD and TKD. The ~35% higher KAM and ~25% higher ρ_{GND} in group 1 relative to group 2 is attributable to the introduction of dislocations by abrasives during MP. Figure 2 shows the ρ_{GND} obtained from group 3 by TKD in the vicinity of a triple junction prior to compression. We will present the results of KAM and ρ_{GND} determination using different diffraction-based techniques with a focus on sample preparation, diffraction pattern formation, and acquisition factors.

This work received support from the National Science Foundation, NSF-1607922.

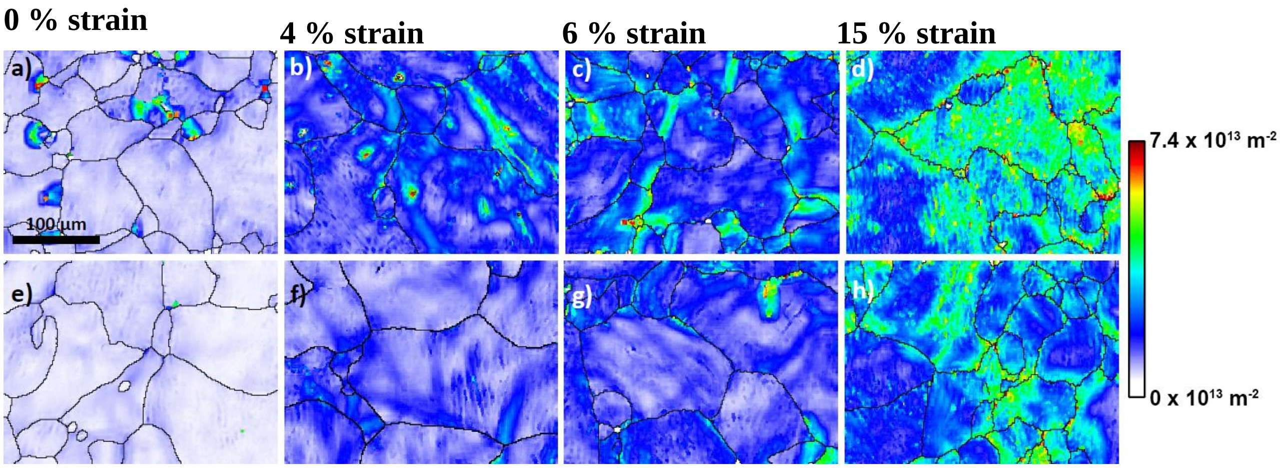

Figure 1. ρ_{GND} map determined from EBSD data. Group 1 (**a-d**) prepared by mechanical polishing; group 2 (**e-h**) prepared by Ar broad ion beam.

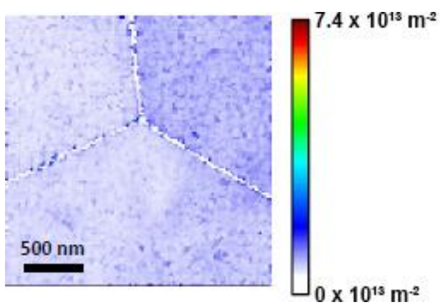

Figure 2. High-resolution TKD maps acquired from Al with 0% strain (group 3).

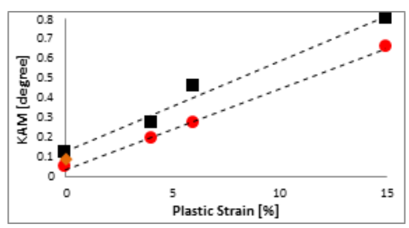

Figure 3. KAM calculated from EBSD and TKD data, which shows linear function to plastic strain.

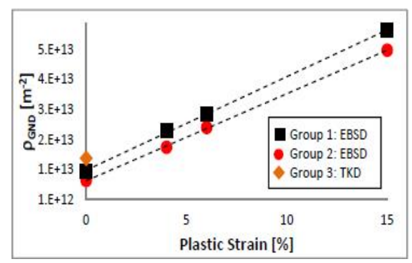

Figure 4. ρ_{GND} calculated from EBSD and TKD data using the dislocation density tensor method.