MISORIENTATION MAPPING FOR VISUALIZATION OF PLASTIC STRAIN VIA ELECTRON BACK-SCATTERED DIFFRACTION

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The ability to map elastic or plastic strain on a microstructural level is critical to understanding and controlling deformation in structural alloys and ceramics. Electron back-scattered diffraction (EBSD) and related techniques, such as electron channeling patterns, have been used with some success to measure the plastic strain around cracks in Fe-3Si single crystals [1], Cu single crystals [2], and Ni-based superalloys [3], among others. However, combining high spatial resolution with the strain sensitivity needed for characterizing the steep strain gradient ahead of a crack tip has been difficult. In this paper, we will discuss the use of misorientation mapping for visualizing plastic deformation at the micron length scale.

Misorientation mapping was performed using standard EBSD mapping techniques with a commercial SEM (CamScan CS44) and commercial software (HKL Inc. Channel 5). EBSD scans were performed on polished 304 stainless steel (austenitic) samples that had been deformed by Vickers indentation. Scans of 120x120 steps of 0.25μm were made on the sample surface.

Different representations of the same data set revealed strikingly different information about the deformation in the indented grain. An Euler angle map (Figure 1) clearly shows the grains in the microstructure and the presence of the indentation, but shows no sensitivity to the plastic strain field associated with the indentation. A pattern quality map (band contrast, Figure 2) displays subtle but perhaps confusing variations in contrast around the indentation corner. A map of the grain boundaries (Figure 3) in the microstructure demonstrates the effect of deformation more directly. The high angle boundaries (black, θ>10˚) are located as expected from the Euler angle map. The low angle boundaries (red, 1˚<θ<10˚), which represent walls or arrays of dislocations, display local gradients in misorientation. A much higher density of low angle boundaries is observed along the edge of the indentation than in the interior of the grain.

Direct mapping of the intragrain misorientation clearly shows the deformation field associated with the indentation (Figure 4). A reference pixel is selected for each grain by using a cluster calculation to identify the minimum gradient in misorientation for that individual grain. The misorientation between the reference pixel and every other pixel is then plotted directly onto the map. Small misorientations (blue) represent small amounts of intragrain misorientations and therefore little deformation. Large misorientations (red) represent large amounts of intragrain misorientations and therefore large deformation. The misorientation map of the indent captures both the deformation field along the edge of the indentation and the deformation zone extending into the grain from the corner of the indentation. These results suggest that this method may have potential for characterizing the strain gradient ahead of crack tips. The current lack of this information is a limitation for crack growth modeling, e.g., for stress corrosion cracking life prediction models [4].

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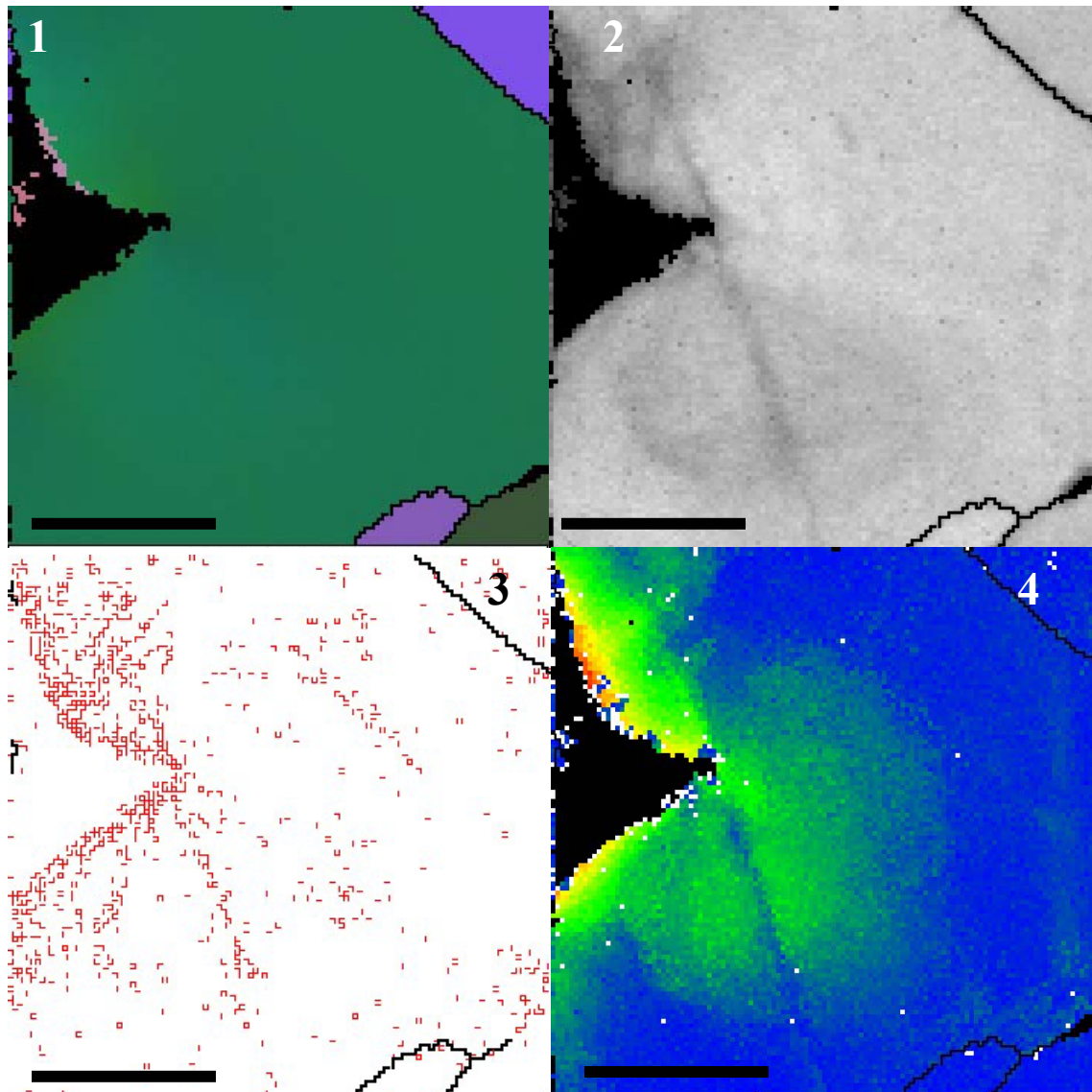
Scale bar on all figures is 10μm.

Figure 1. Euler angle map (each color represents one grain orientation).

Figure 2. Band contrast map (gray scales represent the "quality" of the EBSD pattern.)

Figure 3. Grain boundary map. (black lines are high angle ($\theta>10°$) boundaries, red lines are low angle ($2°<\theta<10°$) boundaries)

Figure 4. Misorientation map (Rainbow scale: blue represents 0° misorientation from reference, red represents 10° misorientation from reference.)