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SPATIAL RESOLUTION OF ELECTRON BACKSCATTER DIFFRACTION IN A FEG-SEM

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Crystallographic information can be determined for bulk specimens in a SEM by utilizing electron backscatter diffraction (EBSD), which is also referred to as backscatter electron Kikuchi diffraction. This technique provides similar information to that provided by selected area electron channeling (SAEC). However, the spatial resolutions of the two techniques are limited by different processes. In SAEC patterns, the spatial resolution is limited to ~2 μm by the motion of the beam on the specimen, which results from the angular rocking of the beam and the aberration of the probe forming lens. Therefore, smaller incident probe sizes provide no improvement in spatial resolution of SAEC patterns. In contrast, the spatial resolution for EBSD, which uses a stationary beam and an area detector, is determined by 1) the incident probe size and 2) the size of the interaction volume from which significant backscattered electrons are produced in the direction of the EBSD detector. The second factor is influenced by the accelerating voltage, the specimen tilt, and the relative orientation of scattering direction and the specimen tilt axis.

This study was performed on a Philips XL30/FEG SEM equipped with a TexSEM Orientation Imaging Microscopy (OIM) system. The signal from the EBSD detector (SIT camera) is flat-fielded and enhanced in a MTI frame storage/image processor. The Schottky FEG source provides the fine probe sizes (~10 nm) desired with sufficient probe current (~1 nA) needed for image processing with the low signal/noise EBSD signal. The EBSD detector is at ~110° to the incident beam direction (i.e.; the forward-scattered direction) and the specimen is tilted 60-80° toward the EBSD detector, in order to increase the number of forward scattered high energy electrons. For a specimen-to-screen distance of ~12 mm, the EBSD patterns subtend an angular range of ~65° by 55°. A disk specimen was cut from a directionally-solidified copper tri-crystal perpendicular to the long columnar grains of the crystal and subsequently electropolished.

Figure 1 shows the image of the grain boundary under the electron optic conditions for EBSP (20 kV, intermediate spot size, 30 μm condenser aperture) with the specimen tilted to 70.4°. The faceted nature of the boundary is evident. However, the roughness of the boundary is exaggerated by the foreshortening (~3x) in the vertical direction of the micrograph, which results from the high specimen tilt. The true included angle between the facets is ~173°. Though similar faceting of the boundary perpendicular to the plane of the specimen is possible, the boundary should be very close to the edge-on orientation. Figures 2a, b are EBSD patterns from the left and right grain at ~1 μm from the grain boundary. From these patterns the misorientation (axis, angle pair) across the boundary is [-0.61 0.64 -0.46], 56.5° and corresponds to a boundary ~8.5° from a $\Sigma = 3$ twin boundary. Figures 2c, d show EBSD patterns from ~50 nm on either side of the boundary and both exhibit only single patterns similar to Figures 2a, b, respectively. When the beam straddles the boundary, both patterns are observed at reduced intensity. The grain boundary image width for secondary electron imaging was ~80 nm, possibly indicating some preferential relief at the boundary. This effect made it difficult to reproducibly position the beam much closer to the boundary.

Similar measurements were made with the specimen rotated 90° around its surface normal. Under these conditions, the spatial resolution for EBSD should be poorer due to forward scattering of electrons from the uppermost grain into the neighboring grain. In addition, as the grain boundary is inclined ~70° from edge-on, there is a contribution from the underlying grain when the beam is located near the boundary in the uppermost grain. Initial results are consistent with this discussion. For the lower grain, single crystal patterns were observed within 100 nm of the boundary, whereas the beam had to be at least 200 nm from the boundary in the uppermost grain to observe a single crystal pattern. The dependence of spatial resolution on accelerating voltage and the constrained combination of spot size and aperture will also be discussed.[1]

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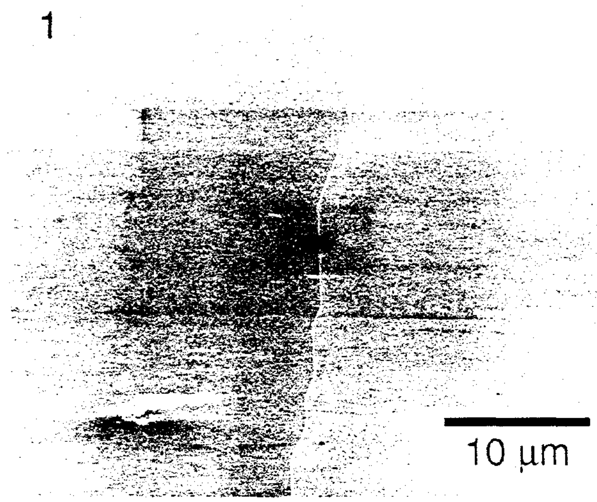

FIG. 1. SE image of faceted grain boundary aligned edge-on at a specimen tilt of 70°.

FIG. 2. EBSD patterns as a function of distance from the grain boundary. Patterns (2a, 2c) in left grain ~1 µm and ~50 nm from boundary; (2b, 2d) in right grain ~1 µm and ~50 nm from boundary.