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EBSD Pattern Quality and its Use in Evaluating Sample Surface Condition

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Modern EBSD systems perform diffraction pattern "quality" (PQ) calculations, essentially measurements of the contrast of the brighter bands in the pattern above background, for every pattern analyzed. Since the calculations are independent of EBSD indexing, data are generated from all points on the analyzed sample surface, regardless of indexability or the state of the material beneath. EBSD maps generated from PQ data are like microstructurally sensitive SEM images, collected at EBSD speeds and grid resolutions, with contrast arising from phase density, crystal structure, crystallographic orientation, grain boundary location, near-surface plastic strain, coating density/thickness, and to some extent topography [1]. Grain boundaries and other aspects of sample microstructure are readily revealed, so the PQ map is a very useful characterization tool in its own right, and serves as a reference for EBSD maps generated from indexing-derived data, such as orientation, grain boundary character, phase distribution and strain maps.

Pattern quality, in essence, is a measurement of how sharp or fuzzy an analyzed diffraction pattern is. To perform the measurement, the EBSD system first performs a Hough transform on the image of the diffraction pattern. To simplify, this involves determining the average intensity along lines of analysis for many positions and inclinations, and plotting these intensities versus line position and orientation. The relatively bright centers of diffraction bands in real space form corresponding "peaks", or intensity maxima, in Hough space. The PQ value for the pattern is then calculated by averaging the height of a selected number of the highest peaks (most intense diffraction bands). Patterns whose strongest bands are higher in intensity than those of other patterns, in general, will generate higher pattern quality values, with correspondingly brighter shades in PQ maps. In theory, a pattern emanating from a volume of crystal with a greater number of crystal defects, especially dislocations, will be less sharp and with a lower average band intensity than a pattern coming from an otherwise identical (phase and orientation), but strain-free, volume of crystal (Fig. 1).

Because of this strain sensitivity and the ease of collecting pattern quality data, some recent interest has focused on pattern quality values at single positions and averaged over areas to evaluate sample surface condition, a critical factor for EBSD. Although pattern quality gives a quantitative metric of prep quality, many factors besides strain contribute to the PQ value and must be considered when performing this kind of analysis. These include: Crystallographic orientation, phase density and crystallographic structure, beam energy & probe diameter, and EBSD system conditions and settings. Thus, although direct quantitative comparison of surface qualities between samples run by different labs, EBSD systems, operators, etc., are difficult due to these very important and fundamental variables, pattern quality is still useful as a relative measure of surface condition between various states of preparation (Fig. 2), but only if all other factors are carefully controlled. It is important to note, however, that modern EBSD systems do not necessarily require the highest possible level of surface preparation to yield their highest quality data. Indexing quality and precision may reach a maximum before the point in the preparation process where pattern quality values do not continue to

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improve. This discrepancy itself depends on several factors, most importantly the material being analyzed, so for any given sample the analyst must make an informed judgment on the extent of preparation necessary to give a sufficiently high surface quality to meet the goals of the analysis.

References

[1] Wright, S.I. and M.M. Nowell, *EBSD Image Quality Mapping*. Microscopy and Microanalysis, 2006. **12**: p. 72-84.

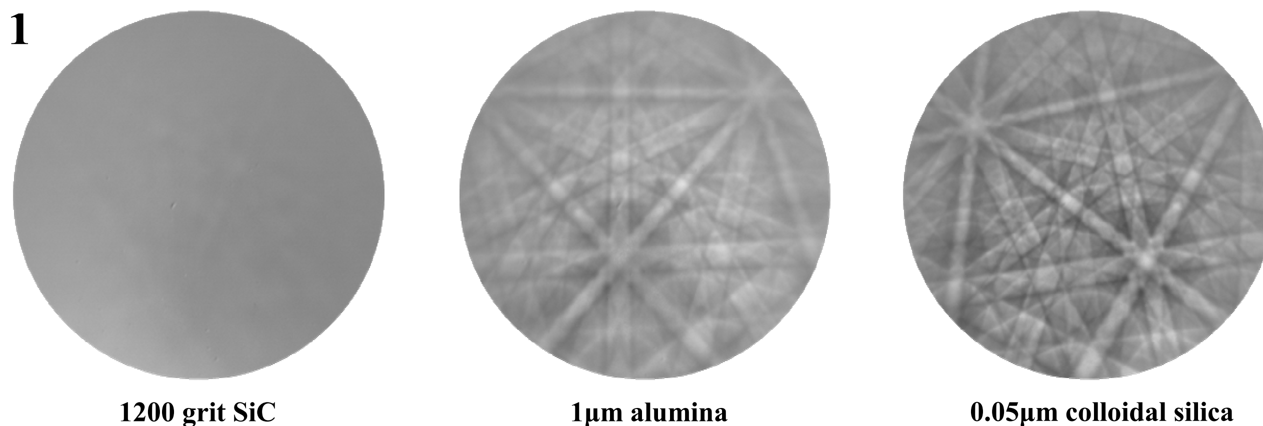

FIG. 1. Electron Backscatter Diffraction (EBSD) patterns from Inconel 600, taken from progressively later steps in a mechanical surface preparation process. Visually, the quality of the patterns improves as preparation-introduced damage is removed. This is quantifiable with the Pattern Quality (PQ) metric.

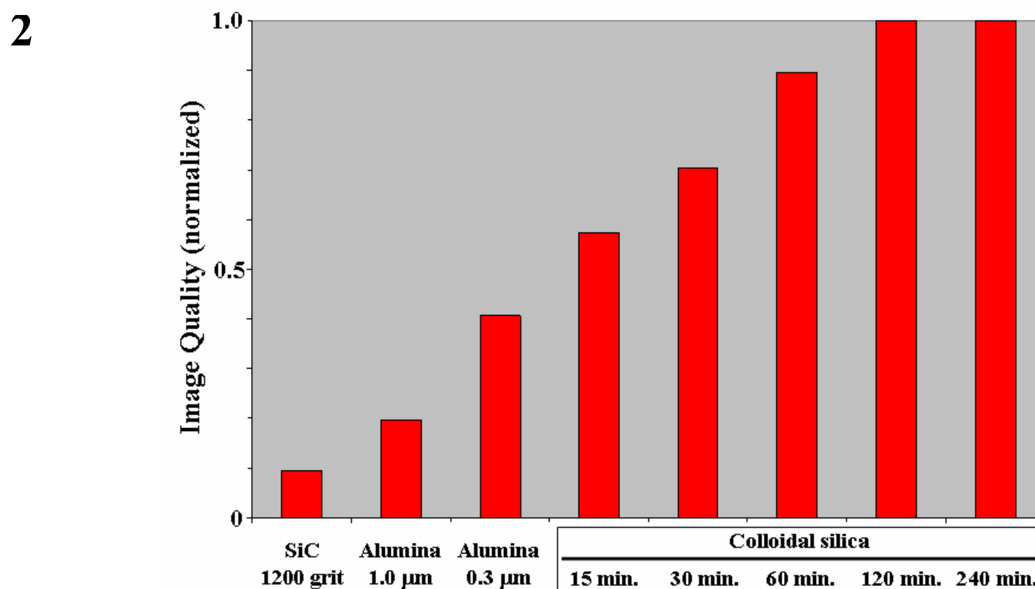

FIG. 2. Graph of normalized average Image Quality (a PQ measurement) vs. preparation step over an EBSD mapping area of Inconel 600. Note that EBSD indexing quality may not increase with PQ beyond a certain point; in this case, the 30 min. step gave a sufficiently high quality surface.

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