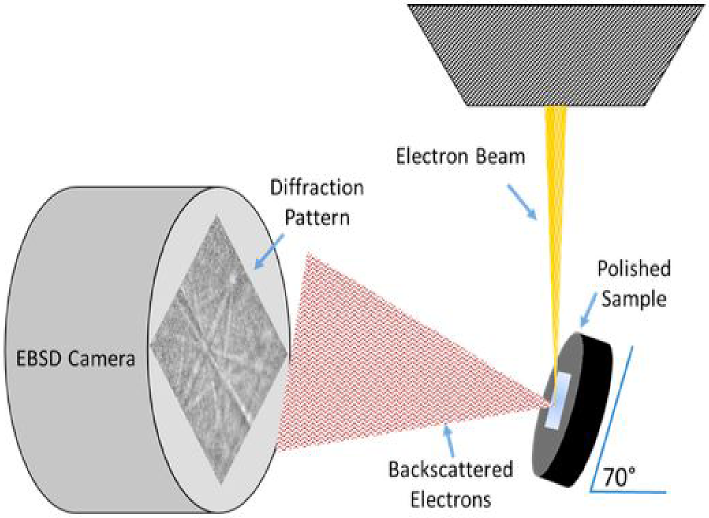
The Characterization Advantage of Electron Backscatter Diffraction (EBSD) Microscopy

An RJ Lee Group Materials Insights Article

Electron backscatter diffraction (EBSD) microscopy is a characterization technique used with scanning electron microscopes (SEMs) for determination of crystallographic information present in both metal and mineral samples.

Much like energy dispersive X-ray spectroscopy (EDS), which provides the elemental composition through the interaction of electron beam and individual atoms, EBSD uses the interaction of the electron beam with a localized, periodic arrangement of atoms to generate diffraction (Kikuchi) patterns that can be captured with an unique camera-beam-detector geometry.

Figure 1. SEM collection geometry for EBSD analysis. A crystalline sample, oriented 70 degree with respect to normal beam incidence, produces a diffraction signal from backscattered electrons that can be collected on a phosphorous screen camera.



The technique provides the ability to determine crystalline phase and orientation information from the analyzed area in a bulk sample and supplements EDS analysis when more detailed structural information is necessary.

EBSD serves as either a complement or alternative to other crystallographic analysis techniques such as transmission electron (TEM) microscopy and x-ray diffraction (XRD), with the added benefit of high-resolution, spatially resolved, phase/orientation mapping.

Unlike TEM analysis, where diffracted electrons pass through the analyzed region, EBSD imaging uses reflected electrons that have diffracted from atoms on the surface of the specimen. By operating as a surface analysis technique, EBSD is well suited for evaluating large polished surface areas, which is often infeasible with TEM, where extremely thin (nanometer) samples and consequently small areas are necessary to limit attenuation of the diffracted signal.

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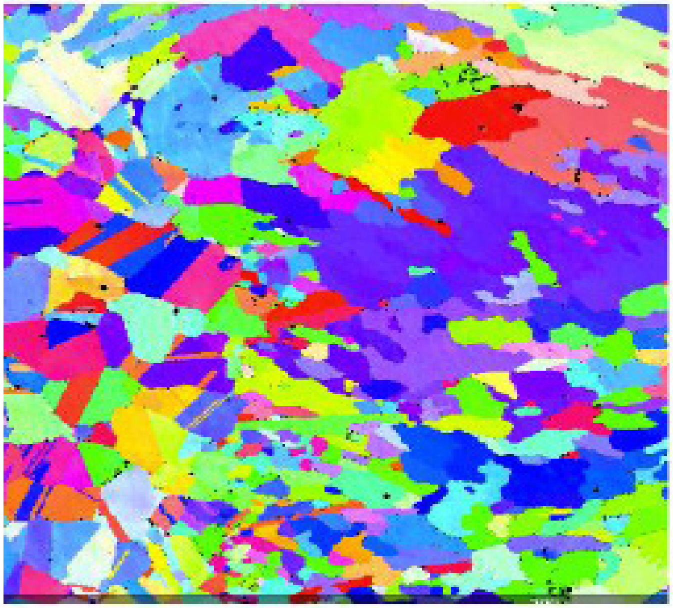

A frequent alternative to TEM is XRD, which uses the interaction of a (poly)crystalline sample with X-rays to produce Bragg diffraction that can be used to quantify the relative abundance of crystalline material phases that may be present in each specimen. Traditional XRD is well suited for the evaluation of powder samples, where randomized orientations yield better X-ray signals and the spatial distribution of phases in the powder solution is typically of minimal interest. Solid materials/polished samples can also be analyzed by XRD to yield texture information, but the analysis is typically used for the identification of preferred orientations via the generation of pole figures and is challenged in producing spatially localized texture information.

Figure 2. EBSD microstructure map collected from a polished surface of a weld interface of C-276 nickel alloy. The coloring scheme correlates with a component of grain orientation.

EBSD serves as a potential alternative to these two techniques, where the ability to scan and map large sample areas (mm) is of interest. Grain size can be determined without the need for etching to reveal the location of grain boundaries. Crystallographic phases can be evaluated when EDS information produces insufficient information as in the case of the iron oxides wüstite (FeO), magnetite (Fe_3O_4) and hematite (Fe_2O_3). Here, EDS is capable of identifying the presence of iron and oxygen but is limited in determining the atomic arrangement of these atoms.

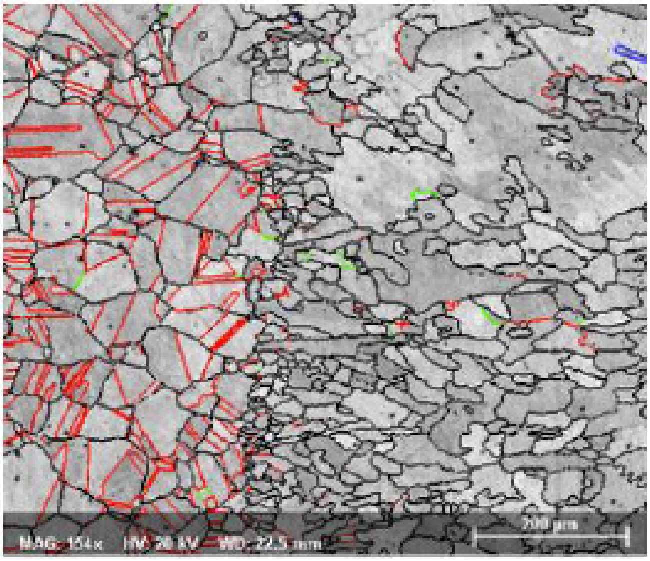

Figure 3. Map illustrating grain boundaries from the microstructure collected in Figure 2. Black lines illustrate grain boundaries, where local misorientation is in excess of 15 degrees. Red, green, and blue lines highlight grain boundar- ies with special misorientation relationships related to the face-centered cubic (FCC) twin configuration. Random high angle grain boundaries are shown in black.

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EBSD can also be used to evaluate the crystallographic texture of a microstructure in the context of both grain and grain boundary orientations. Texture plays an important role in the macroscopic behavior of materials including corrosion behavior, electro-magnetic properties, and mechanical strength.

The ability to map large areas of microstructure affords the production of texture metrics like pole figures, inverse pole figures, and orientation distributions. Grain boundary networks and grain boundary misorientation distributions can also be produced and assist in a greater understanding of the underlying microstructure and its relationship to materials performance.

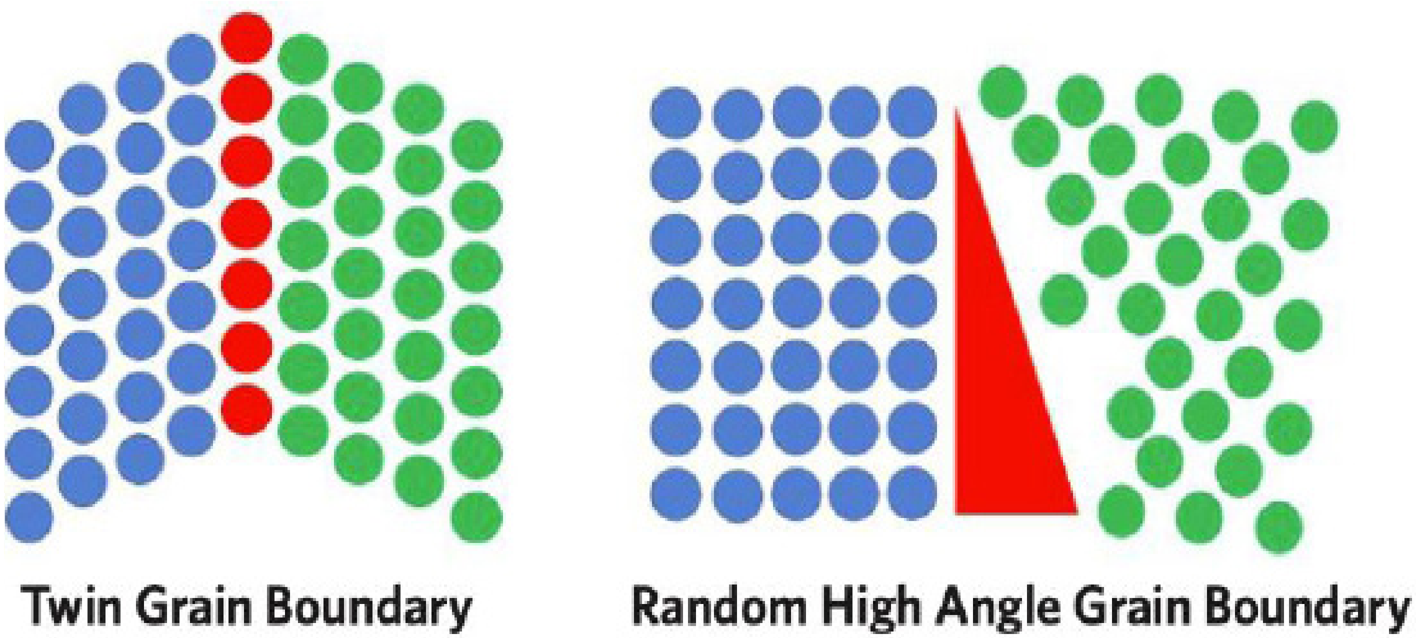

Figure 4 Grain boundary illustration of the difference between an FCC twin configuration and a random high angle grain boundary (HAGB). Atoms from two grains are colored in blue and green, while the interface between the grains is shown in red. While both grain boundaries can be described by a large misorientation angle, the twin grain boundary exhibits a high degree of symmetry that can result in unique material properties. Orientation imaging via EBSD allows for the quantitative characterization of grain boundaries.

References

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Dr. Chris Hefferan is an applied physicist specializing in first principles application to technical problems that caters to a broad range of disciplines and industries. He serves as the principal scientist on unique and complex problems requiring both the rigorous application of the scientific method and an innovative approach to achieve resolution. These investigations often encompass failure analysis of metals and plastics and utilize a diverse suite of techniques ranging from microscopy to analytical chemistry.

Dr. Hefferan is one of the pioneering developers of the synchrotron-based near-field High Energy X-ray Diffraction (nf-HEDM) technique at the Advanced Photon Source (APS) 1-ID beam line at Argonne National Laboratory (ANL).