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Grain boundary character information via individual imaging or statistical analyses: complexion transitions and grain boundary segregation

Katharina Marquardt[1], David Dobson[2], Simon Hunt[2,3], and Ulrich Faul[4]
[1]Department of Materials, Imperial College London, London SW7 2AZ, UK (k.marquardt@imperial.ac.uk)
[2]Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, UK
[3]Department of Materials, University of Manchester, Sackville Street Building, Manches-ter, M1 3BB, UK
[4]Department of Earth, Atmospheric and Planetary sciences, Massachusetts institute of technology, 77 Massachusetts Avenue, 53-918, Cambridge, MA 02139, USA

Grain boundaries affect bulk properties of polycrystalline materials, such as electrical conductivity, melting or bulk viscosity. In the past two decades, observations of marked bulk material property changes have been associated with changes in the structure and composition of grain boundaries. This led to the term “grain boundary complexions” to mark the phase-like behaviour of grain boundaries while differing from phases in the sense of Gibbs (Cantwell 2014).

Here we introduce the principles of grain boundary structure to property relations and potent methods to study these. The focus is on the combination of structural, chemical and statistical analysis as obtainable using transmission electron microscopy and electron backscatter diffraction. Data from these complementary methods will be discussed on two systems; garnet and olivine polycrystals.

Past elasticity measurements showed that the Youngs modulus of garnet polycrystals changes as a function of sintering pressure (Hunt et al. 2016). Here we used high resolution transmission electron microscopy to study the structure of grain boundaries from polycrystals synthesized at low (4-8 GPa) and high (8-15) GPa sintering pressure. The HRTEM data were acquired using an image-corrected JEOL ARM 300 to achieve the highest resolution at low electron doses using a OneView camera. Our data indicate a grain boundary structural change occurs from “low-pressure” to “high pressure” grain boundaries, where the grain boundary facets change from >100 nm – 20 nm to 3-7 nm length scale, respectively. We conclude that sintering pressure affects grain-boundary strength and we will evaluate how this may influence anelastic energy loss of seismic waves through elastic or diffusional accommodation of grain-boundary sliding.

Polycrystalline olivine samples show different viscosity related to grain boundary segregation of impurities. To investigate if the distribution of grain boundaries is affected by grain boundary chemistry, we analysed grain orientation data from over $4x10^4$ grains, corresponding to more than 6000 mm grain boundary length per sample. Using stereology, we extract the geometry of the interfacial network. The thus obtained grain boundary character distribution (GBCD) is discussed

in relation to bulk viscosity.