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3D Microstructural Characterization of Uranium Oxide as a Surrogate Nuclear Fuel: Effect of Oxygen Stoichiometry on Grain Boundary Distributions

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The initial microstructure of an oxide fuel can play a key role in its performance. At low burn-ups, the diffusion of fission products can depend strongly on grain size and grain boundary (GB) characteristics, which in turn depend on processing conditions and oxygen stoichiometry. Serial sectioning techniques using Focused Ion Beam were developed to obtain Electron Backscatter Diffraction (EBSD) data for depleted UO_2 pellets that were processed to obtain 3 different oxygen stoichiometries. The EBSD data were used to create 3D microstructure reconstructions and to gather statistical information on the grain and GB crystallography, with emphasis on identifying the character (twist, tilt, mixed) for GBs that meet the Coincident Site Lattice (CSL) criterion as well as GBs with the most common misorientation angles. Data on dihedral angles at triple points were also collected. The results were compared across different samples to understand effects of oxygen content on microstructure evolution.

The 3D reconstruction of the microstructure of an initial sample of d-$UO_{2.1}$ has been done and the model currently consists of 87 Focused Ion Beam (FIB) slices separated by 0.5 μm, with a total of over 300 grains. This provides enough grains and grain boundaries (GBs) to obtain reliable statistics of correlations between microstructural features, local crystallography and local porosity. The 3-D reconstruction shows that the location of the pores plays an important role in the grain growth and shape. Some large rounded pores located at the grain boundaries (GBs) pin them seem to restrict the local grain growth, which affects the grain shape and leads to local convexity in the GB curvature. This phenomenon was observed in several grains in the microstructure and further studies will benefit from higher resolution FIB serial sectioning in smaller volumes, so the pores can be resolved in 3-D, which is not the case with the existing model.

References:

[1] Nerikar, P.V. ; Rudman, K. ; Desai, T.G. ; Byler, D. ; Unal, C. ; et al. in Journal of the American Ceramic Society (2011) Vol. 94, iss. 6, p.1893-1900
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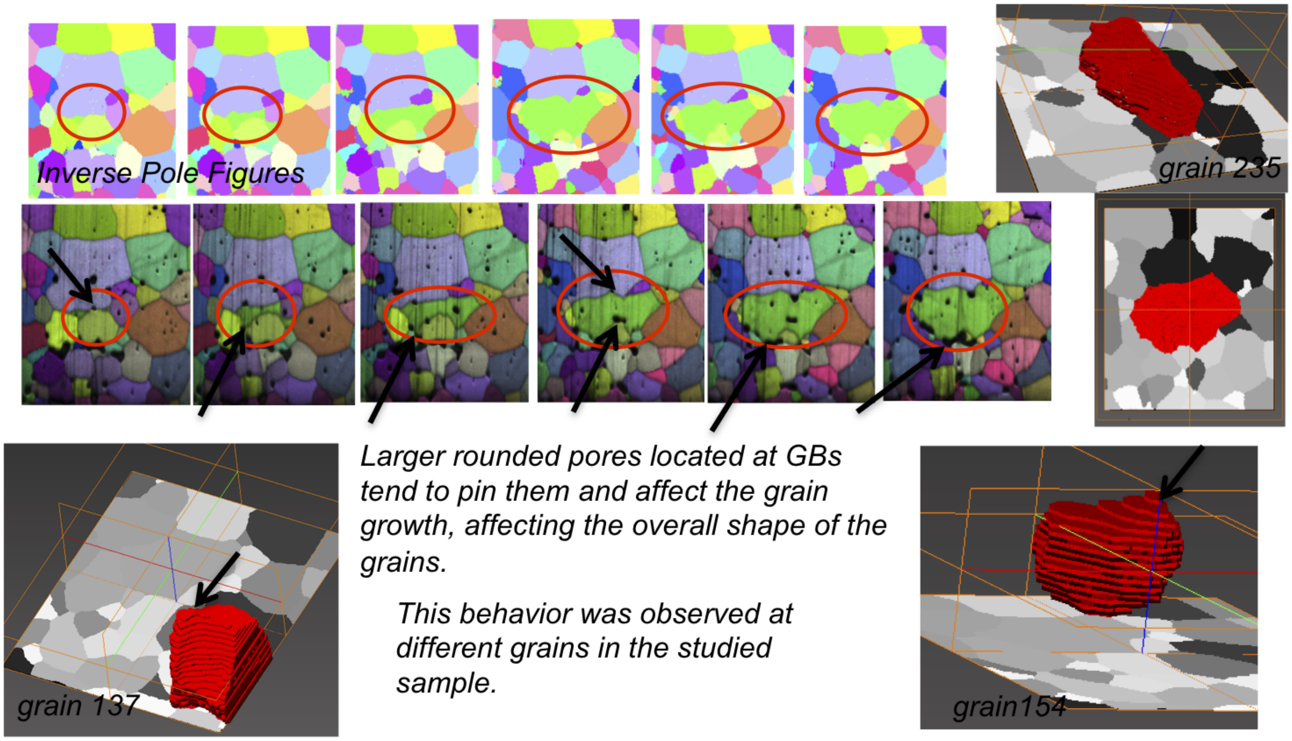

Fig. 1. Inverse pole figure and image quality maps of the microstructure of a sample of d-UO_{2+x} (x ≈ 0.1.

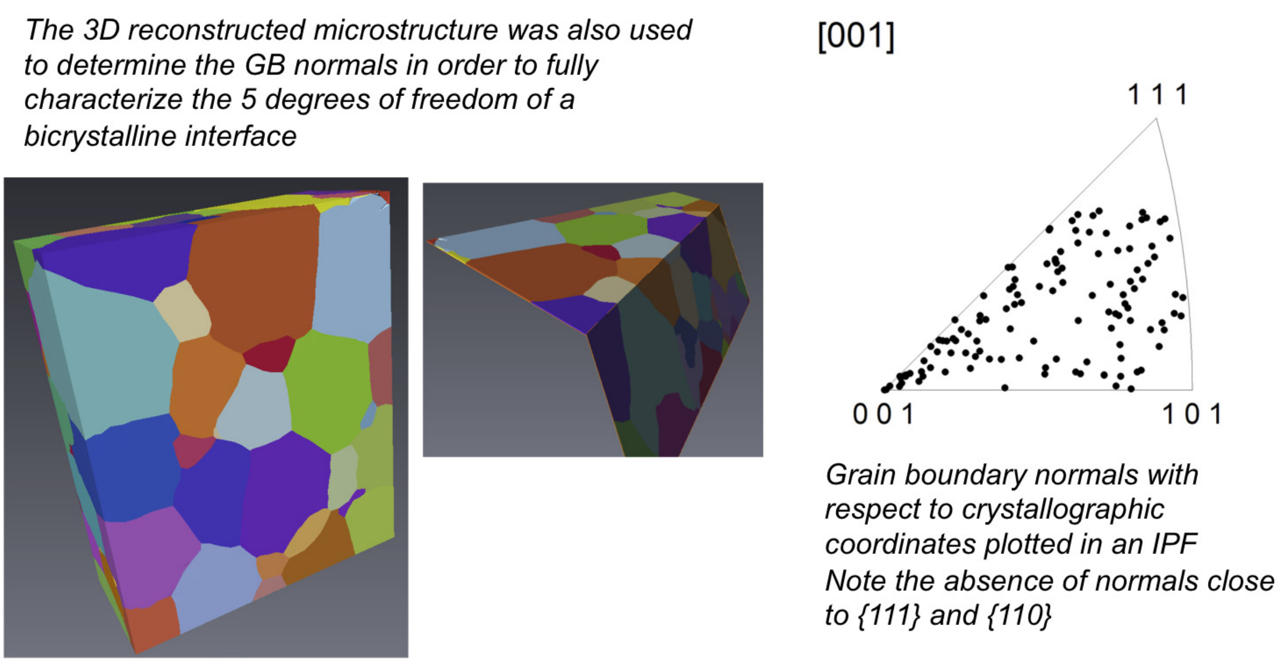

Fig. 2. AVIZO^{TM} reconstructed surface and its cutting planes that reveal grain boundary normals.