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Effect on Processing Conditions on Grain Boundary Character Distribution and Mobility in Oxide Nuclear Fuels

School for Engineering of Matter, Transport and Energy

Karin Rudman Prieto

Advisor: Pedro Peralta

abstract

The initial microstructure of oxide fuel pellets can play a key role in their performance. At low burnups, the transport of fission products has a strong dependence on oxygen content, grain size distribution, porosity and grain boundary (GB) characteristics (crystallography, geometry and topology), all of which, in turn, depend on processing conditions. These microstructural features also affect fuel densification, thermal conductivity and microstructure evolution inside the reactor. However, experimental data relating processing parameters to GB characteristics are scarce and much needed to understand microstructural evolution in-pile. In this work, serial sectioning techniques were developed to obtain 2-D and 3-D microscale crystallographic data, using Electron Backscatter Diffraction, for depleted-UO2+X pellets. The samples were fabricated under different processing conditions, including various densities, sintering ramp rates and stoichiometry. The data were used to establish how processing conditions, in general, and oxygen to metal ratio (O/M), in particular, can affect microstructural features such as grain size, shape, fraction and distribution of special GBs, porosity, with emphasis on GB character. Abnormal grain growth was observed in all samples, regardless of the fabrication process. The crystallography of these large grains (2.5X the average grain size) and their GBs was analyzed. Results indicate that the crystal orientation of these grains dominate the overall texture of the samples. Furthermore, all of the large grains had at least 6 neighbors regardless of the O/M; and a preferential <001> rotation axis. These results could be related to GB energy and structure, as the literature suggest that low energy GB tend to dominate the GB texture over more mobile GBs in more “mature” microstructures to minimize energy of the system. Among the possible hypothesis to explain these results an enhanced diffusion of point defects and defect clusters that could aid GB diffusion at these GBs seems to be the most plausible, although further studies will be required to fully understand these findings. The results presented in this work indicate that detailed studies of the initial microstructure of the fuel, could give insights on the in-pile microstructural evolution of the fuel, as certain GBs tend to drive the evolution of the microstructure.

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