INTRODUCTION

Ceramic oxide nuclear fuel pellets are the most commonly employed fuel for the nuclear energy industry in the US and abroad. Standard fabrication methods; i.e. cold press and sinter, are used to generate hundreds of pellets per minute. Defects such as cracking, poor dimensional control and density variations are still inherent to this process. As the US enters a nuclear renaissance, revisiting traditional ceramic processing methods to elucidate the relationship between processing and microstructure using modern tools is expected to lead to new insights.

DESCRIPTION OF THE ACTUAL WORK

Various microstructural attributes can influence the properties of a fuel pellet. Porosity and grain structure are two aspects that have received considerable attention. These parameters influence factors such as fission gas release and the stability of the microstructure in pile. In this study, pellets were fabricated from different starting uranium oxide powders using standard cold press and sinter techniques. The powders were conditioned and characterized prior to fabrication. Pressing behavior was observed. Pellets were sintered under an argon atmosphere at two temperatures in order to observe the temperature effect on grain growth. Scanning Electron Microscopy (SEM) and Electron Backscatter Diffraction (EBSD) were used to study grain size, size distribution, orientation and morphology.

RESULTS

Figure 1 shows the green density of powders as a function of pressure. Sigma powder was milled and sieved while the AREVA powder was pressed as received and the ABB was pressed in both conditions. As seen in the figure, the ABB powder shows a greater density to pressure dependence than the other powders. This tends to result in pellets with localized variations in the green density within the compact, an undesirable state.

With 15 minutes of milling, the green density of a pellet made from Sigma powder was 59.8% and sintered to a density of 89.4% at 1350 °C. With 1 hour milling time, the green density was 63% and the sintered density was 85%. Improving the green density of the pellet did not have the intended affect of improving sintered density. Although powder flow was improved allowing us to achieve a higher green density, the additional milling reduced the activity of the powder resulting in a lower fired density. The reduced activity was addressed by removing particles with a lower activity by sieving. After sieving the powder, a green density of 65% was achieved and a sintered density of 92%. This powder conditioning approach i.e., extended milling and sieving, can then be viewed as the correct path for this powder; even though optimization of the approach is required.

Electron backscatter images of uranium oxide pellets made from Sigma powder that was sintered at 1330 and 1680°C showed little difference in grain size, shape and orientation. The images confirm the similarity in microstructure between the samples. No preferred grain orientation could be determined from the images. The average grain size of the pellet prepared at 1330°C was determined to be 4.8 µm while the grain size at 1680°C was 5.2 µm which was considered statistically insignificant. Figure 2 graphically illustrates the measured grain size distributions. This data indicates sluggish grain growth kinetics for uranium oxide even in a dense, sintered pellet at temperatures below 1680°C.

The impact of powder source on compaction, sintering and shrinkage behavior was investigated. The type of powder used strongly affects the green density during compaction regardless of powder conditioning steps prior to compaction verifying the interdependence of processing steps and the impact on the microstructure of the ceramic pellet. Surprisingly grain growth was found to be relatively independent of sintering temperature for Sigma powder.

Fig. 2 Grain size distributions determined from EBSD images of sintered pellets.

REFERENCES