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Effect of the heating rate on the sinterability of UO_2-10wt%CeO_2

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1. Introduction

A MOX(Mixed OXide) pellet(UO_2-PuO_2) is a major fuel for the next generation nuclear power reactors. The fabrication of a MOX pellet is generally similar to a powder metallurgy. It is generally known that the compositions, sintered density and pore size and their distribution in the MOX pellet are dominant factors for maintaining a longer cycle operation in power reactors[1]. An increased content of the additive oxide leads to a higher burn-up. However, it is known that a manufacturing of a higher content of the additive oxide is not easy due to the homogeneity of a powder mixture.

In this work, CeO_2 powder was used instead of PuO_2 powder. Nuclear chemical properties of CeO_2 are similar to those of PuO_2. The effect of the heating rate on the UO_2-10wt%CeO_2 pellet under an oxygen(CO_2) atmosphere is investigated. Heating rate is a important control parameter of the sintered density and microstructure[2].

2. Experimental method

UO_2 and CeO_2 powder are mixed for 1 hr in a mixer. And the mixed powder is milled to minimize the particle size and to homogenize the powder mixture, 4 hrs in a Dynamic Milling device. Green pellets are prepared by a hydraulic press with a compaction pressure of 300 MPa. These green pellets are sintered at 1500℃ for 4 hrs under a CO_2 atmosphere with various heating rates(0.5~8℃/min). Sintered density and grain size of the UO_2-10wt%CeO_2 pellets were measured by an immersion method with water and by an intercept method, respectively. And the shrinkage(%) of these pellets was measured with a TMA-92 device (Setaram, France).

3. Results and discussion

Fig. 1 and Fig. 2 show the sintered density and the grain size of the UO_2-10wt%CeO_2 pellet as a function of the heating rates under a CO_2 atmosphere, respectively. As shown in Fig. 1, the sintered density of the UO_2-10wt%CeO_2 pellet decreased as the heating rate increased. And Fig. 2 shows that the grain size of the UO_2-10wt%CeO_2 pellet decreased with an increasing heating rate. As a result, a lower heating rate is necessary to creat both a larger grain size and a higher sintered density of the UO_2-10wt%CeO_2 pellet under these sintering conditions. Fig. 3 shows the grain structure of the UO_2-10wt%CeO_2 sintered pellet according to various heating rates.

Fig. 4 shows densification curves of the UO_2-10wt%CeO_2 pellets as a function of the heating rate. From these densification curves, the three points-densification starting temperature(T_{DS}), the solid solution formation temperature zone(T_{SS}) and the densification ending temperature(T_{DE}) - are acquired. That is, as the heating rate of the UO_2-10wt%CeO_2 pellet increased, the densifcation starting temperature, the solid solution formation temperature zone and the densifcation ending temperature increased. For example, T_{DS}, T_{SS} and T_{DE} at the heating rate of 0.5 ℃/min. are 650 ℃, 850~1210 ℃ and 1380 ℃, respectively. But at the heating rate of 8 ℃ T_{DS}, T_{SS} and T_{DE} are 760 ℃, 970~1300 ℃ and 1430 ℃, respectively. Detailed values of these parameters are given in Fig. 4.

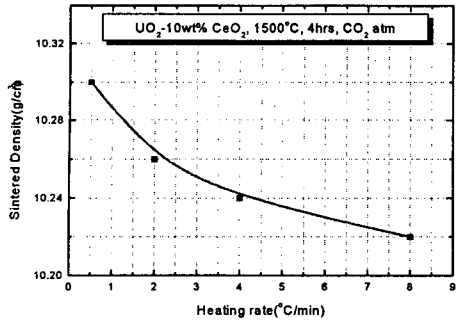

Fig. 1. The sintered density of the UO_2-10wt%CeO_2 pellet as a function of the heating rate

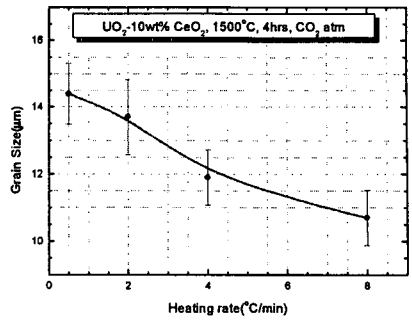

Fig. 2. The grain size of the UO_2-10wt%CeO_2 pellet as a function of the heating rate

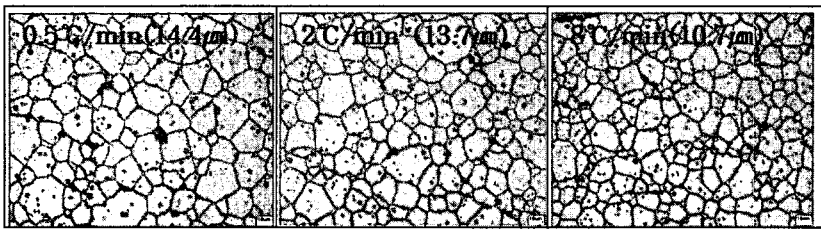

Fig. 3 The grain structures of UO_2-10wt%CeO_2 pellet as a function of the heating rate

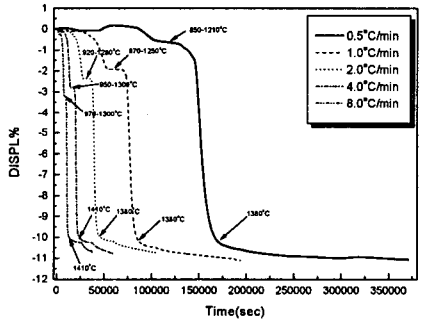

Fig. 4 The shrinkage of the UO_2-10wt%CeO_2 pellet as a function of the heating rate

4. Conclusions

Results of the experiments described in this work lead to the following conclusions :

- Both the sintered density and grain size of the UO_2-10wt%CeO_2 pellet increased with an increasing heating rate.
- The densification starting temperature, the solid solution formation temperature zone and the densifcation ending temperature increased as the heating rate increased.

Acknowledgements

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Reference

1. IAEA-TECDOC-584(91-021-02), February 1991
2. Randall M. German, "Sintering Theory and Practice," John Wiley & Sons, Inc., (1996)171