Control of Resintering Behavior of UO_2 Fuel Pellets by Modifying the Microstructure

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1. Introduction

Pores in UO_2 fuel pellets and fission gas bubbles which were generated during the fuel irradiation were converted to vacancies by the interaction with fission fragment.[1] These vacancies shifted to the grain boundary and then diffused out to open-pores. As a result of the vacancy diffusion, UO_2 fuel pellets were re-densified and the dimension of pellets was decreased. This resintering behavior of UO_2 fuel pellets during the irradiation affect the fuel performance of nuclear fuel rods[2]. It is important to control the pore structure of the UO_2 pellets in order to enhance their dimensional stability during the irradiation. [3]

Zinc stearate is frequently used for a lubricant in UO_2 pellet fabrication process. Small amount of Zinc stearate is mixed with UO_2 powder and made to pellets. It is volatilized in the initial stage of sintering and forms a irregular-shape-pore.[4] It is known that TiO_2 is able to accelerate facilitation of grain growth and form a round-shape-pore.

This paper deals with the resintering behavior of UO_2 fuel pellets which contain additives of Zinc stearate and TiO_2.

2. Experimental and Results

ADU UO_2 powder was mixed with various contents of high purity titania powders for 1 h and then 0.5 wt% zinc stearate was mixed with these powder mixture for 0.5 h in a tumbling mixer. The powder mixture was compacted into a green pellet with a pressure of 300 MPa. Green pellets of UO_2 and UO_2 containing 0.1, 0.2 wt% TiO_2 and 0.5, 1.0 wt% zinc stearate were prepared. These green pellets were sintered at 1730℃ for 4 h in H_2 flowing gas. The resintered pellets were prepared by resintering the sintered pellets at 1700℃ for 24 h in flowing H_2 gas.

The density of the sintered and re-sintered pellets was measured by using an immersion method. Ceramographic samples of re-sintered pellets were prepared by a mounting, grinding, polishing and etching the pellets. The pellet was cut in the axial direction. And then a grinding and polishing process was performed. To observe the grain structure, a thermal etching for the polished samples was carried out at 1250 ℃ for 2h in a CO_2 flowing atmosphere. The microstructure of the samples was observed by an optical microscopy. The grain size of the sample was measured by using the linear intercept method.

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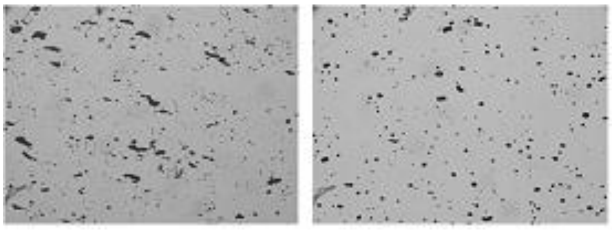
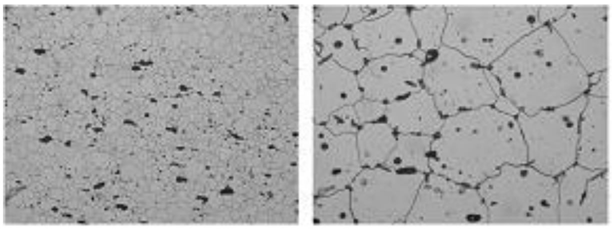


(a) (b)

Figure 1. The pore structure of ADU UO_2 pellets(×200)
(a) 0.5 wt% Zinc stearate (b) 0.5 wt% Zinc stearate + 0.1 wt% TiO_2

Figure 1 shows the pore structure change of Zinc stearate doped UO_2 pellets according to the addition of TiO_2. The shape of pores in Fig. 1(a) is irregular. Many tiny pore exist in Fig.1(a). However, when the TiO_2 was doped in this pellets, shape of pores become round and the number of micro-pores was remarkably decreased.



(a) (b)

Figure 2. The grain structure of ADU UO_2 pellets(×200)
(a) 0.5 wt% Zinc stearate (b) 0.5 wt% Zinc stearate + 0.1 wt% TiO_2

The grain structures of resintered UO_2 pellet are shown in Figure 2. The grain size of Zinc stearate doped UO_2 pellet is about 11.5 μm. The grain size of Zinc stearate and TiO_2-doped UO_2 pellet increased up to about 46.5 μm. This grain size is four times larger than the zinc stearate doped UO_2 pellet. Most of pores were located at the grain boundary in Fig.2(b).

Fig.3 shows the densities of sintered and resintered pellets. Fig. 3(a) shows the resintered density changes of un-doped UO_2 pellets. In spite of the density difference of UO_2 pellets before resintering, the final resintered pellet density was similar to each other. Fig. 3(b) shows the density change of sintered and resintered pellets in zinc stearate doped UO_2 system. In contrast to Fig.3(a), density increased in the resintered pellet is independent to the initial sintered pellet density. Fig. 3(c) shows the sintered and resintered pellet density of zinc stearate and TiO_2 doped UO_2 pellets. The resintered pellet density is the largest in the low density pellets as like in fig. 3(a). However, resintered pellet density increment is considerably mitigated in these pellets.

3. Conclusion

Pores of an irregular shape were formed in Zinc stearate doped UO_2 pellets. Pores of a round shape were formed in TiO_2 doped UO_2 pellet.

Re-sintered density increment was mitigated in the pellets which have irregular shape pore structure. It was found that re-sintered density increment could be controlled by controlling the pore structure of UO_2 pellets. The pore structure of sintered pellet can be controlled by combining the addition of zinc stearate and TiO_2.

ACKNOWLEDGEMENT

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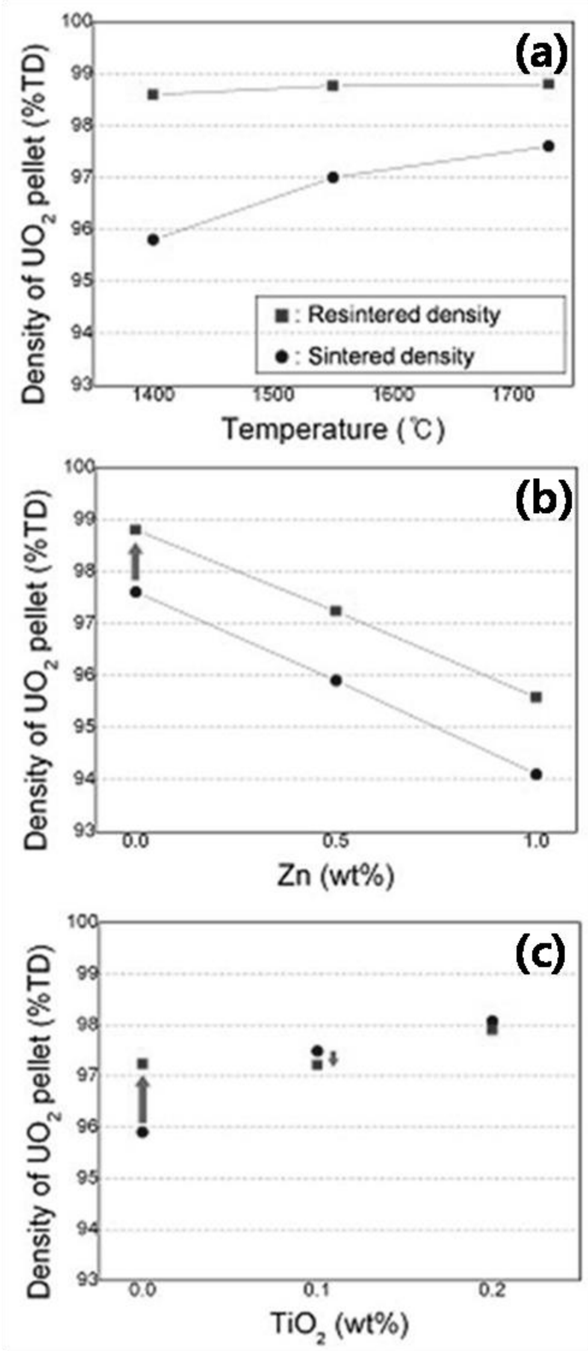

Figure 3. The density change after re-sintering UO_2 pellets; (a) Pure UO_2 (b) Zinc stearate doped UO_2 (c) 0.5wt% Zinc stearate + TiO_2 doped UO_2