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Sintering Behavior of B_4C-dispersed UO_2 Pellet

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1. Introduction

Boron is the only non-rare-earth neutron absorbing materials commercially used as an integrated burnable absorber fuel form. The Integral Fuel Burnable Absorber (IFBA) of Westinghouse is the sintered UO_2 fuel pellets with a thin coating of zirconium diboride (ZrB_2) on the outer surface by sputtering. Because of this additional coating process, the fabrication cost of IFBA fuel increased by 20% to 30%. [1]

If the boron-dispersed UO_2 fuel pellet can be fabricated by the conventional powder-metallurgical process from a powder mixture of UO_2 and B compound, it would be more cost-effective than IFBAs. In late 60s, Combustion Engineering [2] tried to develop the sintering process of boron-dispersed UO_2 green pellet. However, they reported that boron-dispersed UO_2 fuel pellet is very difficult to be fabricated with a sufficient level of boron retention and high sintered density (greater than 90 % of theoretical density) because of the volatilization of boron oxide.

Recently, we found that boron compounds seemed to act as a sintering additive for UO_2 at a certain low temperature range. [3-5] A high density BN-added UO_2 pellet can be fabricated after sintering at 1200 °C for more than 1 h in a H_2 atmosphere. The sintered density of BN-added UO_2 pellet can be increased up to about 95 %TD. [6]

In the performance aspect of boron-bearing fuel, He formation and release characteristics would be the most important point, which affect the rod internal pressure. In case of BN, N_2 could be formed after ^{10}B transformed to He and Li. It might be worse effect on the rod internal pressure. Thus, metallic boride were considered such as B_4C, TiB_2, ZrB_2 and so on.

In this study, the sintering behavior of B_4C-added UO_2 pellet has been investigated by sintering green pellets of a mixture of UO_2 powder and B_4C powder in H_2 atmosphere. B_4C has higher boron content than that of BN and it might produce less gas phase than BN.

2. Experimental

ADU route UO_2 powder and B_4C powder were used for sample preparation. UO_2 powder, B_4C powder and various kinds of sintering agents were mixed in a tumbling mixer for 2 h and then pulverized in a mortar. The powder mixtures were mixed with a 0.3 wt% of zinc stearate in a tumbling mixer for 30 min. The compaction was conducted in a single acting press under about 3 ton/cm^2. Green pellets were sintered at various temperatures from 1350 °C to 1650 °C for 2 h in a H_2 atmosphere. The sintered density was measured

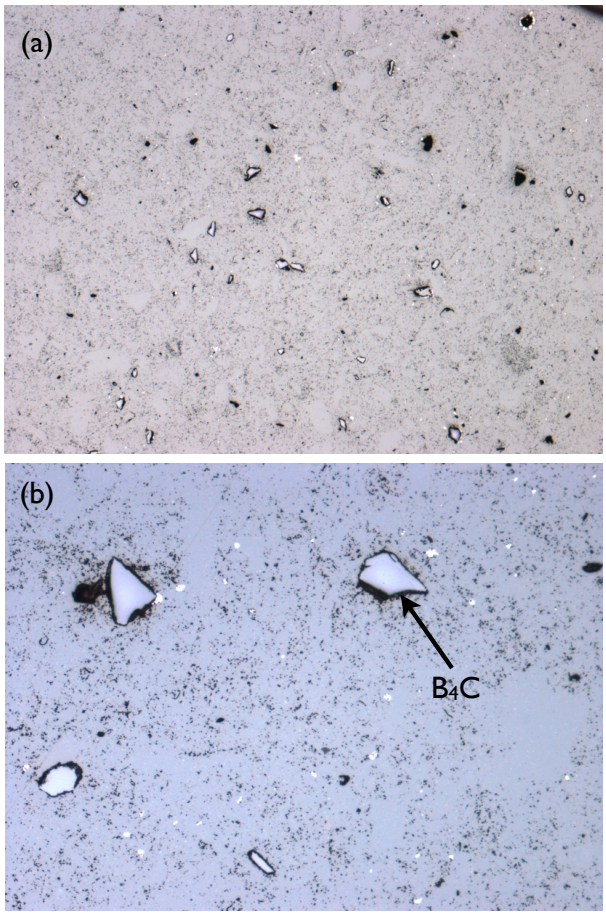

Fig. 1. Microstructures of B_4C-dispersed UO_2 pellet. (a) X50 and (b) X200.

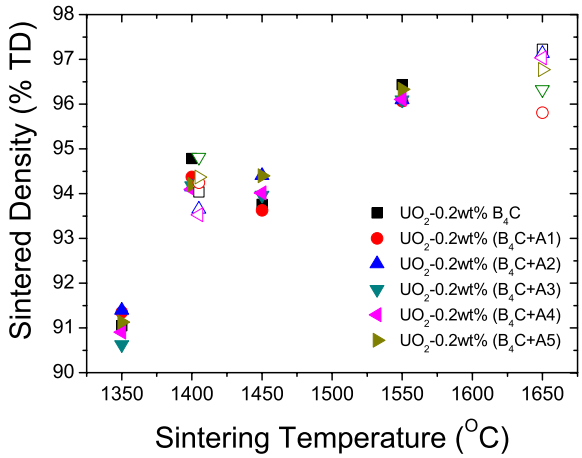

Fig. 2. Sintered densities of B_4C-dispersed UO_2 pellets with various sintering agents.

by a water immersion method. Microstructures were observed using an optical microscope after polishing the cross-section of the sintered pellet up to a 1 μm diamond polish. Residual boron content in the sintered pellets was measured by ICP method.

3. Results

Microstructures of sintered B_4C-dispersed UO_2 pellets were shown in Fig. 1. It seems that B_4C particles are well dispersed in UO_2 matrix. High magnification photo clearly shows the angular shape of B_4C particles. Figure 2 represented the measured sintered densities of sintered pellets with various sintering agents according to the sintering temperature. It appears that the densification of B_4C-dispersed UO_2 pellet is significantly enhanced at the sintering temperature of higher than 1400 °C. B_4C-dispersed UO_2 pellet can be densified up to higher than 95 % of theoretical density at the sintering temperature of higher than 1550 °C for more than 2 h in a H_2 atmosphere. Effect of sintering agents on the sintered density seemed not to be significant. But, they may affect the residual boron contents in sintered pellets. Residual boron content measurements are under conducting by ICP method.

4. Conclusions

A high density B_4C-dispersed UO_2 pellet can be fabricated after sintering at 1550 °C for more than 2 h in a H_2 atmosphere. The sintered density of B_4C-dispersed UO_2 pellet can be increased up to about 97 %TD. Sintering agents seemed to have little effect on the sintered density, but their effect on the residual boron content in the sintered pellets need to be checked.

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