

Fabrication of Boron-containing Burnable Absorber Fuel Pellet

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1. Introduction

Burnable absorber fuels refer to nuclear fuels containing strong neutron absorbers. Lanthanides such as gadolinium, erbium, europium and samarium could be used as neutron absorbing materials. The sintered (U,Gd)O₂ pellet has been employed as a burnable absorber in the most of commercial light water reactors in order to suppress the initial excess reactivity at the beginning of life.

Boron is also a neutron absorber which can be burned out or depleted during reactor operation. Boron is known to be more favorable for a long fuel element cycle. While the burnup characteristic of gadolinium is optimal for 12-month fuel element cycles, the burnup characteristic of boron is optimal for 18-month fuel element cycles. [1]

In the viewpoint of a fabrication, however, previous study [2] reported that boron-dispersed UO₂ fuel pellet is very difficult to be fabricated with an enough level of boron retention and a high sintered density (greater than 90 % of theoretical density) because of the volatilization of boron oxide. During the sintering of the green pellet of the powder mixture of UO₂ and boron compound such as B₄C, BN, TiB₂, and ZrB₂, boron oxide formed from the boron compound oxidation by adsorbed moisture and excess oxygen in UO₂. The poor sinterability is attributed to the presence of boron oxide as liquid or vapor phases at all sintering temperature.

M. Peehs et al.[1] reported that boron-containing UO₂ pellets with high sintered densities can be produced by sintering a compact comprising a mixture of UO₂ powder and UB₄ powder at 1700 °C for 2 h in H₂ atmosphere. It could be attributed to the more oxidation resistance of UB₄ phase.

He also reported that an uniformly boron-distributed high density pellet can be fabricated by sintering a compact comprising a mixture of UO₂ powder and B₄C powder at 1150 °C for 2 h in CO₂ atmosphere and reducing the pellet at 1150 °C for 1.5 h in H₂ atmosphere. High oxygen partial pressure of CO₂ atmosphere enhances the diffusivity of uranium ion and enables a green compact to be sintered and formed a densely sintered UO₂ structure at low temperature prior to the significant volatilization of boron oxide. The densely sintered UO₂ structure could prevent a further volatilization of boron oxide.

Those results have some disadvantages or limitations, such as the necessities of the UB₄ powder synthesis and the swelling problems due to the entrapped CO₂ gas.

In this study, we are trying to fabricate the boron-containing UO₂ pellet by using a mixture of UO₂ powder and BN powder in a sintering atmosphere of H₂ gas. We introduce a new low temperature sintering

technique in reducing atmosphere through the sintering additive, MnO.

2. Experimental

Samples were prepared with ADU route UO₂ powder, 70 nanometer-sized BN powder and MnO powder. UO₂ powder were mixed with 0.1 wt% of BN powder in a ball mill for 12 h by using an ethanol medium. A sintering additive added UO₂ - 0.1 wt% BN powder mixture was also prepared by the same method except of adding 0.2 wt% of MnO powder. Dried powder mixture was granulated with 30 mesh sieve. The granules 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/cm². The powder compacts were sintered at 1100 °C for 1 to 4 h in H₂ atmosphere. Sintered density was measured by the water immersion method. Microstructures were observed by using an optical microscope after polishing the cross-section of the sintered pellet up to 1 μm diamond polish.

3. Results

Figure 1 shows the sintered boron-containing pellets of UO₂ - 0.1 wt% BN and UO₂ - 0.1 wt% BN - 0.2 wt%

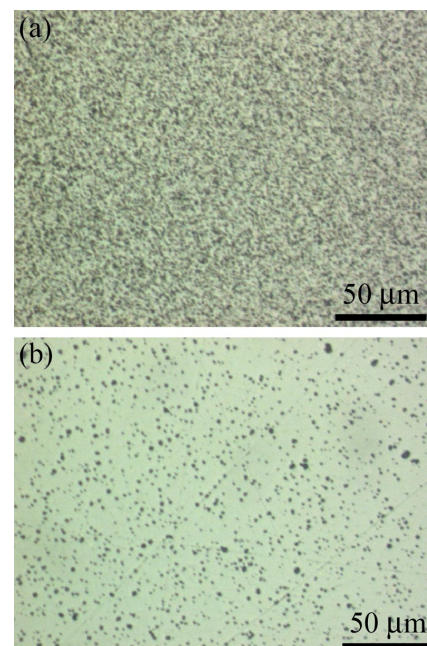


Fig. 1. Microstructures of the sintered boron-containing pellet; (a) UO₂ - 0.1 wt% BN and (b) UO₂ - 0.1 wt% BN - 0.2 wt% MnO.

MnO after sintering at 1100 °C for 4 h in H₂ atmosphere. The sintered density of MnO-added sample appeared to be much higher than that of none added sample. The sintered density of UO₂ - 0.1 wt% BN pellet was gradually increased with a sintering time up to about 87 %TD after sintering for 4 h. However, UO₂ - 0.1 wt% BN - 0.2 wt% MnO pellet has the sintered density of about 94 %TD even after sintering for 1 h and the sintered density was increased up to around 96 %TD after sintering for 4 h.

4. Conclusions

Boron-containing UO₂ pellet with the high density of greater than 94 %TD can be fabricated by using a low temperature sintering technique in H₂ atmosphere. A small amount of MnO, a sintering additive, could enormously enhance a materials transfer during sintering even at a very low sintering temperature in H₂ atmosphere.

ACKNOWLEDGMENTS

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