Fabrication of UO_2 pellet containing shape-controlled metallic phase

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1. Introduction

Thermal conductivity is one of the most important properties of the UO_2 pellet in a nuclear fuel, because it extremely affects the in-reactor performance, integrity and safety of the nuclear fuel.

A phonon is primarily responsible for the thermal conduction in ceramic materials. The phonon is not as effective as free electron. So, thermal conductivity of ceramic materials is generally lower than that of metallic materials. The thermal conductivity of uranium oxide which is a typical ceramic material is low as well. The steep temperature gradient in the fuel pellet results from the low thermal conductivity.

Therefore, the thermal conductivity improvement of a nuclear fuel pellet can enhance the fuel performance in the various points. The lower centerline temperature of fuel pellet affects the enhancement of fuel safety as well as fuel pellet integrity during a nuclear reactor operation. Besides, the nuclear reactor power can be uprated due to the higher safety margin.

To improve the thermal conductivity of UO_2 pellet, the UO_2-cermet composite is one of the most effective concepts [1-3]. The ‘cermet’ is derived from the nature of the constituents of a ceramic and a metallic phase.

However, the increment of thermal conductivity of the pellet fabricated using the metallic dopant which simply mixed with UO_2 is a little [4]. The metallic phase in the UO_2 matrix must be controlled to the profitable structure to raise the efficiency of phonon conduction [5-7].

In this study, we intended to appropriately control the shape of the metallic phase in the UO_2 matrix. The pellet was fabricated by using the shape-controlled powder mixture of Mo-metal with UO_2.

2. Experimental

5 wt% molybdenum powder (STREM Chemicals, 99.9%) was added to ADU-UO_2 (Ammonium Diuranate). And then, two methods (simple mixing and ball milling) of powder treatment were used. That is, one powder mixture simply mixed by using a Turbula mixer for 2 h. Another powder mixture was milled by using a planetary mill (FRITSCH, Purvelisette 6) for 1~8 h.

The prepared powder mixtures were compacted by using a single acting press at about 300 MPa, and sintered at 1730 ºC for 4h in a flowing H_2 atmosphere.

The sintered density of the pellet was determined by using a gas pycnometer (Micrometritics, AccuPyc II 1340). And a microstructure of the sintered pellet was observed by using optical microscopy.

3. Results

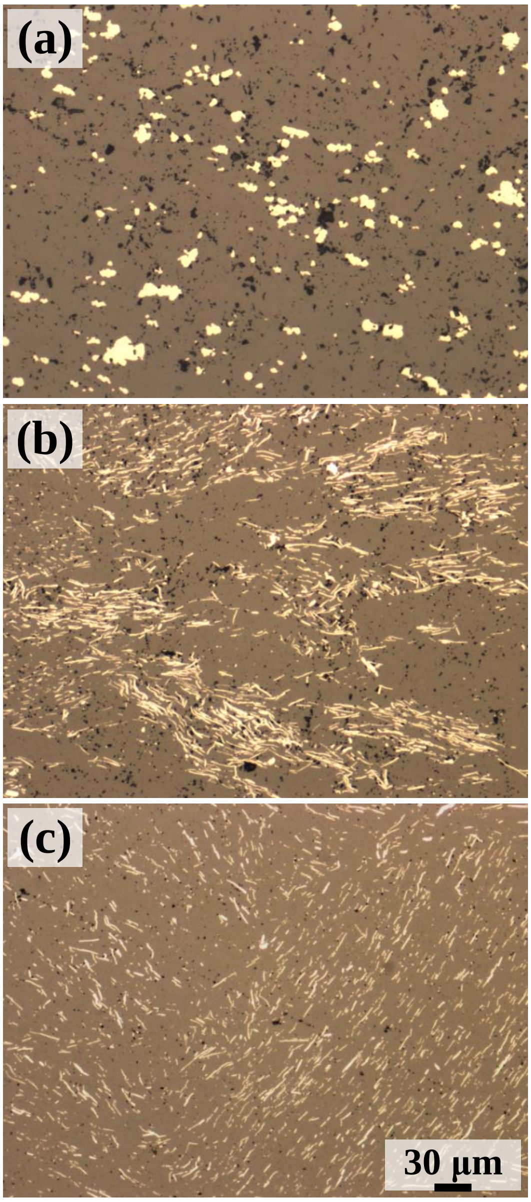

Figure 1. The optical microscopic image (×200) of UO_2 pellets containing shape-controlled metallic phase: powder mixture milled for (a) 0 h, (b) 5 h, (c) 8 h.

Figure 1 shows a microstructure of UO_2 pellets containing the shape-controlled metallic phase. In the UO_2 pellet fabricated by using the simple mixed powder mixture, the agglomerated Mo-metallic phase which is about several tens of size could be observed (Figure 1 (a)). Average particle size of added Mo-metal powder was 3~7 μm.

The shape-changed Mo-metallic phase is shown in the Figure 1 (b) and (c). The shape of metallic phase was changed into the wire type by the physical contact with the alumina ball during the powder milling process. Moreover, the connected metallic phases can be partly observed.

The thermal conductivity of the pellet fabricated by using these shape-controlled powders is expected to be higher than that of the pellet containing the non-treated and isolated metallic phase.

In the Figure 1 (c), the distribution of metallic phase in the UO_2 matrix was more homogeneously changed. The effect of the homogeneity of distribution of shape-controlled metallic phase on the thermal conductivity will be experimentally verified by our ongoing measurement test for the pellets.

Figure 2 shows a sintered density of UO_2 pellets containing the shape-controlled metallic phase. Density of pellet using simply mixed powder is lower than that of fresh UO_2 pellet. However, density of pellets using milled powder mixture gradually increased with increasing the milling time, because the sinterability of UO_2 powder enhanced by the milling process.

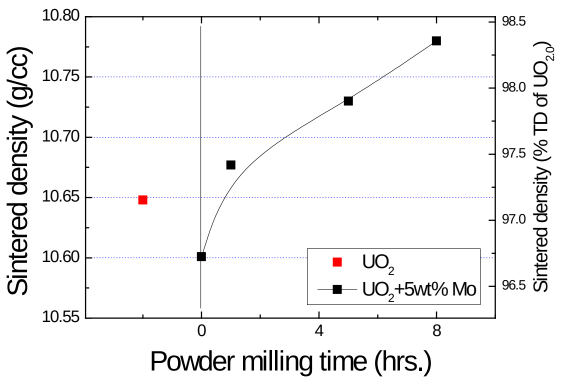

Figure 2. The sintered density of UO_2 pellets containing shape-controlled metallic phase.

4. Summary

To enhance the thermal conduction in the UO_2 pellet, we intended to appropriately control the shape of the metallic phase in the UO_2 matrix. The metallic phase shape could be changed into the wire type by using a ball milling process for the powder mixture. The pellet was fabricated by using the treated powder mixture of Mo-metal with UO_2, and then, the characteristics of the fabricated pellet were investigated.

The thermal conductivity of the pellet fabricated by using this method is expected to increase, and the measurement test of the thermal conductivity of these pellets is in progress.

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