Optimization of Additive-Powder Characteristics for Metallic Micro-Cell UO_2 Fuel Pellet Fabrication

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1. Introduction

The thermal conductivity of a UO_2 fuel pellet is one of the most important thermal properties in the nuclear fuel of an LWR. The steep temperature gradient and high centerline temperature in the fuel pellet results from a low thermal conductivity of UO_2, which is a typical ceramic material. The in-reactor performance, integrity, safety and accident tolerance of the nuclear fuel can be affected by the thermal conductivity of the fuel pellet [1, 2].

The improvement in the thermal conductivity of the UO_2 fuel pellet can enhance the fuel performance in various aspects. The mobility of the fission gases is reduced by the lower temperature gradient in the UO_2 fuel pellet. That is to say, the capability of the fission gas retention of the fuel pellet can increase.

In addition, the lower centerline temperature of the fuel pellet affects the accident tolerance for nuclear fuel as well as the enhancement of fuel safety and fuel pellet integrity under normal operation conditions. The nuclear reactor power can be uprated owing to the higher safety margin.

Thus, many researches on enhancing the thermal conductivity of a nuclear fuel pellet for LWRs have been performed [3-5]. Typically, an enhancement of the thermal conductivity of the UO_2 fuel pellet can be obtained by the addition of a higher thermal conductive material in the fuel pellet. To maximize the effect of the thermal conductivity enhancement, a continuous and uniform channel of the thermal conductive material in the UO_2 matrix must be formed.

In this work, to fabricate a Cr metallic micro-cell UO_2 fuel pellet with a continuous and uniform Cr metallic channel, the optimization test about the Cr metal powder characteristics was performed.

2. Experimental and Results

Cr metallic micro-cell pellets were prepared using the fabrication process which was shown in our previous paper [6]. ADU-UO_2 (Ammonium Diuranate) powder was pre-compacted using a single acting press, and a pre-compact was crushed and sieved (granulation).

Cr metal powder at 5 vol% (Ditto Technology, 99.9%) was mixed with the prepared UO_2 granule using a simple mixing method. The powder mixtures were compacted and sintered under conventional UO_2 pellet compaction/sintering conditions.

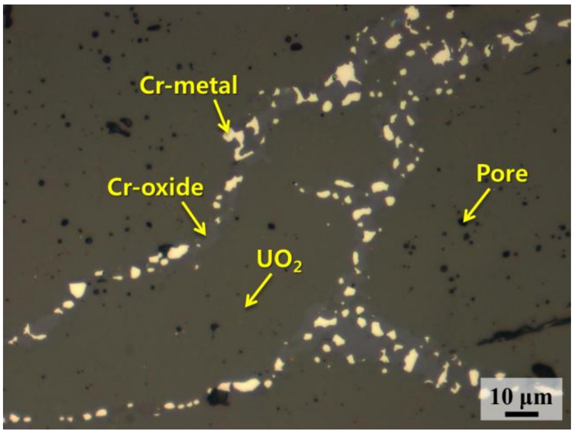

Fig. 1. Microstructure of Cr metallic micro-cell UO_2 pellet which was fabricated using nano-sized (~200 nm) Cr metal powder.

The sintered density of the Cr metallic micro-cell UO_2 pellet was determined using an immersion method, and a microstructure of the sintered pellet was observed using optical microscopy.

First, from the view point of making the continuous and uniform distribution of Cr metallic phase, small-sized metal powder can be more favorable [6]. So, in the fabrication of Cr metallic micro-cell pellet, the nano-sized (~200 nm) Cr metal powder was used (Figure 1). However, the formation of Cr-oxide phases in Cr metallic cell-walls of the fabricated pellet was occurred, because of high oxygen affinity of nano-sized Cr metal powder due to large specific surface area. The

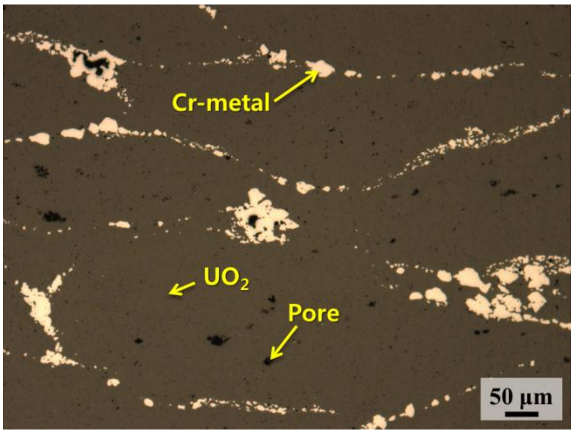

Fig. 2. Microstructure of Cr metallic micro-cell UO_2 pellet which was fabricated using micro-sized (5~10 µm) Cr metal powder.

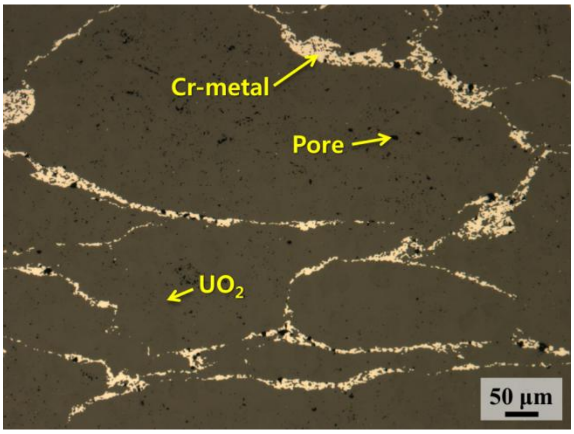

Fig. 3. Microstructure of Cr metallic micro-cell UO_2 pellet which was fabricated using Cr metal powder with plate-shaped type.

effect of thermal conductivity enhancement of fuel pellet will be decreased by the Cr-oxide phases.

To decrease the oxygen affinity of Cr metal, the micro-sized (5~10 μm) Cr metal powder was prepared, and the Cr metallic micro-cell pellet was fabricated using the same process condition.

Figure 2 shows the microstructure of the fabricated pellet, and the Cr-oxide phases are not observed because of the lower specific surface area of Cr metal powder. However, connectivity and uniformity of Cr metallic phase in UO_2 matrix was relatively worsened due to the large particle size of Cr metal powder.

To prevent the formation of the Cr-oxide phases and simultaneously enhance the uniformity of the Cr metallic phase distribution, we intended to optimize the shape of the added Cr metal powder using the milling process.

In the results, as it can be seen in Figure 3, the Cr metallic micro-cell pellet with continuous and uniform Cr metallic channel was obtained. It is expected to increase the effect of the thermal conductivity enhancement of fuel pellet.

3. Summary

To enhance the thermal conductivity of a UO_2 fuel pellet, the development of fabrication process of a Cr metallic micro-cell UO_2 pellet with a continuous and uniform channel of the Cr metallic phase was carried out. The formation of the Cr-oxide phases was prevented and the uniformity of the Cr-metal phase distribution was enhanced simultaneously, through the optimization of the additive-powder characteristics. In the results, the Cr metallic micro-cell pellet with continuous and uniform Cr metallic channel could be obtained.

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