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Development of Mo Microplate aligned UO_2 Pellets for Accident Tolerant Fuel

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1. Introduction

Recently, the paradigm of nuclear fuel research has been changed from enhancing economic efficiency to improving accident tolerance for safety issue after the Fukushima accident. It seems to have reached a consensus on that the current LWR fuel should be tolerable to severe accidents to mitigate their consequence with maintaining the performances. Thus, various concepts of new fuels are being suggested and developed under the name of accident tolerant fuels (ATF).

One of the current issues for nuclear UO_2 fuel pellet is about its low thermal conductivity. The low thermal conductivity leads to increase thermal gradient in the fuel pellet and centerline temperature when in operation. Enhancing the thermal conductivity of UO_2 fuel pellet is greatly attractive in the aspect of fuel performance [1–3] and also for its safety margin. The fuel pellets having high thermal conductivity can lower fuel temperature and reduce the mobility of the fission gases [4–6]. In addition, a reduced temperature gradient within the pellet probably enhances the dimensional stability, with lower thermal stress of the fuel pellet, thus the pellet cladding mechanical interaction (PCMI) and even in fuel fragmentation, relocation and dispersal (FFRD) can be mitigated. A thermal margin gained from the high thermal conductivity of pellet would be utilized in a safe operation of LWR or even power-uprate operation also. There have been efforts on enhancing the thermal conductivity of the fuel pellet. One of the methods is introducing high thermal conductive materials into fuel pellets. Yang et al. [7] have shown experimentally that the thermal conductivity of a UO_2 pellet can be increased substantially by providing a UO_2 pellet with connected tungsten channel. KAERI has also developed micro-cell UO_2 fuel pellets consist of granules enveloped by thin metallic cell walls. [8-10] The metallic cell walls in pellets are continuously connected to each other, enhancing thermal conductivity.

In this study, to enhance the thermal conductivity in radial direction, molybdenum metal plate-shaped particles were dispersed in a UO_2 fuel pellet. Micrometer-sized thin Mo plates, as we called it Mo microplates, were aligned horizontally in a UO_2 pellet to have enhanced thermal conductivity with heat transfer paths in radial direction. Moreover, the compatibility in the fuel fabrication process can be enhanced, due to the simple pellet fabrication method. The thermal properties of the pellets were characterized with the microstructures of the fuel composite.

2. Experimental and Result

A Mo microplate UO_2 pellet was fabricated by composing UO_2 and Mo microplate powders.

Mo microplates were prepared by milling spherical Mo powder particles. Mo metal powder was milled in a planetary milling machine and Mo microplate powder was prepared.

3 vol.% of Mo microplates were simply mixed in a tubular mixer with UO_2 powder. The powder mixture was compacted using a uniaxial press at about 300 MPa, and the pelletized green body was sintered at 1730 ºC for 4h in a flowing H_2 atmosphere.

The sintered density of a Mo microplate pellet was determined using an immersion method, and a microstructure of the sintered pellet was observed using optical microscopy and SEM. The size distribution of grains in the pellet was investigated, and found to be the size of grains were satisfied with fuel pellet production control conditions.

Fig. 2 shows the microstructure of a Mo microplate UO_2 pellet. The bright phase of Mo microplates were dispersed homogeneously and aligned in horizontal direction in UO_2 pellet, which is forming the effective thermal conductive paths for radial heat transfer.

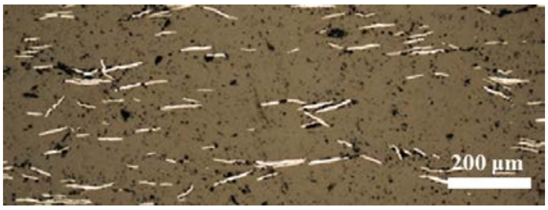

Fig. 2. Microstructure of a Mo microplate UO_2 pellet.

Thermal conductivity of the pellet was characterized by LFA method. The pellet was sliced in axial direction to measure the effective radial thermal conductivity. The radial thermal conductivity was much enhanced compared with pristine UO_2, and even also higher than the conductivity of the UO_2 pellet with same amount of spherical Mo particles included. (Fig. 3) This enhancement of the thermal conductivity of the Mo microplate UO_2 pellet was mainly affected by the shape and arrangement of the metallic plates in the pellet. The effect on the thermal conductivity with the Mo plates was investigated.

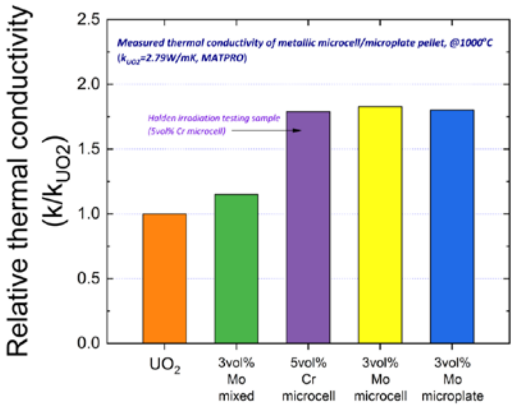

Fig. 3. Comparison of thermal conductivities of UO_2 fuel pellets at 1000^{o}C.

3. Summary

In this study, Mo microplate UO_2 nuclear fuel pellet was fabricated for enhancing the thermal conductivity of the pellet. Mo metal microplates were aligned working as heat conducting paths in the pellet. Therefore, the thermal conductivity of the UO_2 pellet in radial direction could be enhanced, which can lead to reduce thermal gradient of the pellet when in operation in a reactor. Considering the outstanding fuel pellet characteristics, this Mo microplate UO_2 pellet will be one of the promising fuel concepts of ATF pellets in near future.

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