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Fabrication of Integrated Burnable Absorber Fuel Pellets with Enhanced Thermal Conductivity

Dong Seok Kim*, Dong-Joo Kim, Jae Ho Yang, Ji-Hae Yoon and Heung-Soo Lee
Nuclear Fuel Safety Research Division, Korea Atomic Energy Research Institute
**Corresponding author: dskim86@kaeri.re.kr*

1. Introduction

Since the beginning of the nuclear power generation, many of efforts have been focused on increasing the economic efficiency in operation. However, in the wake of Fukushima accident, and it becomes more important very recently, that the current fuel should be tolerable to severe accidents to mitigate their consequence with maintaining the performances. As the consequences, it becomes mandatory to facilitate safe fuels like ATF(Accident tolerant fuel) on nuclear power plants according to the green taxonomy.

On the other hand, nuclear power plant utilities have to make business in a very competitive against other renewable energy industries. Therefore, it is required to increase the economic competitiveness through the use of nuclear fuels which could achieve very high burnups, beyond 70 GWd/MTU. In order to reach and surpass this value may be necessary to work with uranium enrichments higher than the traditional 5% limit [1].

A longer fuel cycle which is needed to enhance the load factor of nuclear power plants also requires development of new burnable absorber with adequate functions. Nuclear fuels that will be able to burn well beyond 70 GWd/ MTU necessarily need to have, among other things, uranium enrichments higher than 5%, thus leading to the necessity of using extremely efficient burnable poisons [1]. A strategy for designing high-burnup fuels is to increase the thermal conductivity of the fuel pellets. In the current UO_2 fuels, Gd is doped as a burnable poison to control their burnup. However, Gd doping also reduces the thermal conductivity because of an increase in phonon-point defect scattering [2].

KAERI has developed UO_2 fuel pellets with enhanced thermal conductivity [3-6]. Enhancing the thermal conductivity of UO_2 fuel pellet is greatly attractive for its safety margin with lowered centerline temperature, and even in the aspect of fuel performance. Fission products, especially gaseous species are inevitably produced during the operation, can affect to the structures of the nuclear fuel system. The fuel pellets having high thermal conductivity can lower fuel temperature and reduce the mobility of the fission gases.

In order to enhance the thermal conductivity, metallic particles were dispersed in a UO_2 fuel pellet. Micrometer-sized thin molybdenum particles were aligned 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 fuel pellet with enhanced thermal conductivity has been proposed as a promising ATF pellet candidate.

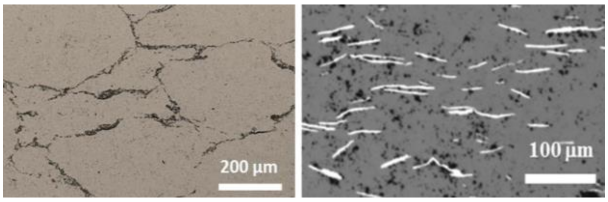

Fig. 1. Microstructures of a UO_2-Mo pellets with enhanced thermal conductivity.

In this study, in order to enhance thermal conductivity of an integrated burnable absorber fuel pellet, metallic particles were embedded in the integrated burnable absorber fuel pellet. Mo particles were aligned in (U, Gd)O_2 and (U, Er)O_2 pellets to have enhanced thermal conductivity with heat transfer paths in radial direction. The thermal properties of the pellets were characterized with the microstructures of the fuel composite.

2. Experimental and Result

Integrated burnable absorber pellets were made by conventional solid-state reaction method. 8 wt% Gd_2O_3 doped $(U_{0.89}Gd_{0.11})O_2$ UO_2 and 2 wt% Er_2O_3 doped $(U_{0.97}Er_{0.03})O_2$ UO_2 pellets were prepared and also the Mo particles were dispersed in the pellets to have enhanced thermal conductivity. (see Table 1.)

Sample label	Description
U	UO_2
UM	UO_2 + Mo
UG	UO_2 + Gd_2O_3(8wt.%)
UGM	UO_2 + Gd_2O_3(8wt.%) + Mo
UE	UO_2 + Er_2O_3(2wt.%)
UEM	UO_2 + Er_2O_3(2wt.%) + Mo

Table 1. Integrated burnable absorber pellet samples and the corresponding labels.

Rare earth oxides for burnable absorber materials such as Gd_2O_3 and Er_2O_3 particles were mixed with UO_2 and grounded by planetary milling for a better sinterability and attaining homogeneous mixture. Mo particle was also added and mixed, then pressed into a green pellet.

The green pellets were sintered at 1730ºC for 4 h in a flowing H_2 atmosphere with some oxygen partial pressure to obtain designated sintered density.

The sintered densities of sample pellets were determined using an immersion method, and a microstructures of the sintered pellets were observed using optical microscopy and SEM. The pellet integrity was found to be sound and the microstructural properties were satisfied with fuel pellet production control conditions.

Thermal conductivities of the integrated burnable absorber pellets were characterized by LFA method. The pellets were sliced in axial direction to measure the effective radial thermal conductivity. The radial thermal conductivity of the pellets with embedded Mo particles was enhanced compared with conventional BA pellets. This enhancement of the thermal conductivity of the Mo pellet was mainly affected by the and arrangement of the metallic particles in the pellet. The effect on the thermal conductivity with the Mo particles was also investigated.

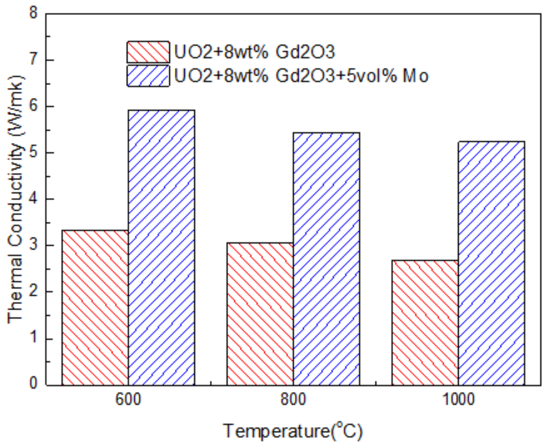

Fig. 3. Comparison of thermal conductivities of $(U,Gd)O_2$ fuel pellet at different temperatures.

3. Summary

In this paper, integrated burnable absorber fuel pellets with aligned Mo particles were fabricated and investigated with the enhanced thermal conductivity. Mo particles in BA pellets worked as heat conducting paths in the pellet, therefore, the thermal conductivity of the UO_2 pellet in radial direction could be enhanced. It can lead to reduce thermal gradient of the pellets, enables to consider increasing enrichment of fuels for longer cycle with burnup extension with margin of safety and economy.

ACKNOWLEDGEMENT

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