Fabrication of Micro-cell UO_2 Pellet for HALDEN Irradiation Test

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1. Introduction

A micro-cell UO_2 pellet is being developed in KAERI (Korea Atomic Energy Research Institute) to enhance the accident tolerance of nuclear fuels under accident conditions as well as the fuel performance under normal operation conditions [1].

The micro-cell UO_2 pellet consists of UO_2 grains or granules enveloped by thin cell walls. Depending on the materials used for making the cell walls, there are ceramic and metallic micro-cell UO_2 pellets.

The ceramic wall in ceramic micro-cell UO_2 pellets is composed of oxides having chemical affinity to volatile fission products such as Cs or I, which are highly radioactive and corrosive fission products, and act as multiple traps to immobilize the volatile fission products. That is to say, the ceramic micro-cell walls can block the migration of fission products to the pellet outside. The increased retention capability of fission products will reduce the stress corrosion cracking at the inner surface of cladding as well as the rod internal pressure.

By implementing the metallic cell walls with high thermal conductivity, the thermal conductivity of a micro-cell UO_2 pellet can be increased. The mobility of the fission gases is reduced by the lower temperature gradient in the UO_2 fuel pellet. That is, the capability of the fission product retention of the fuel pellet will increase. In addition, the micro-cell UO_2 pellet with high thermal conductivity will significantly increase the safety margin under design basis accidents such as a loss-of-coolant accident (LOCA) as well as the thermal margin under normal operation conditions [2].

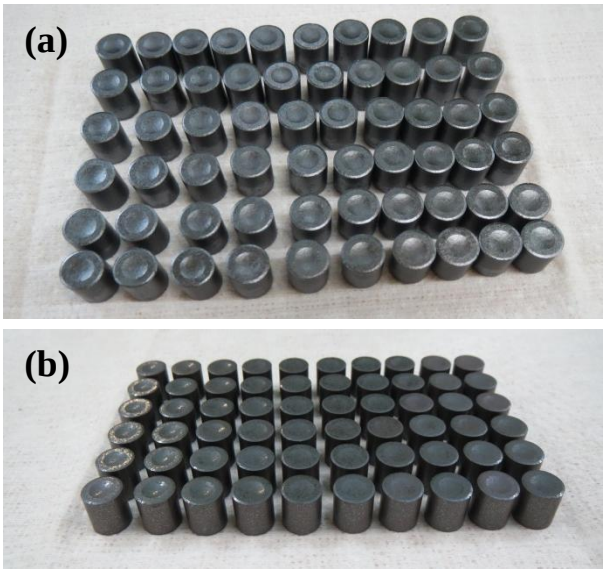

Fig. 1. Two kinds of fabricated samples for irradiation test; (a) ceramic and (b) metallic micro-cell UO_2 pellets.

In the development of nuclear fuel, the irradiation behavior of the developed fuel material must be considered based on various aspects (pellet microstructure, cell wall soundness, cell wall material behavior, pellet structural integrity, etc.). Above all, it is important that the designed in-reactor fuel performances of the micro-cell UO_2 pellet are verified.

To investigate the irradiation behaviors of the micro-cell UO_2 fuel pellet materials, a HALDEN irradiation test is planned for two kinds of micro-cell UO_2 pellets. This paper reports the specifications of the fabricated micro-cell UO_2 pellets for the irradiation test.

2. Irradiation Test Plan and Pellet Specifications

Through the cooperation with Thor Energy, a HALDEN irradiation test of the micro-cell UO_2 pellets will be performed. KAERI is participating in the International Thorium Consortium organized by Thor Energy. In the consortium, several consortium members (the Institute for Transuranium Elements (ITU), Germany; Fortum, Finland; National Nuclear Laboratory (NNL), U.K.; Westinghouse, U.S.) are participating.

The irradiation test rigs with instrumentations will be manufactured at the Institute for Energiteknikk (IFE), Norway. Table 1 shows brief information for the irradiation test.

Two kinds (ceramic and metallic) of micro-cell UO_2 pellets were fabricated [3, 4] in accordance with the requirements for the HALDEN irradiation test. The number of samples (~60 EA) was sufficiently provided to manufacturing the instrumented rigs. The prepared pellet specifications are shown in Table 2.

Table 1. Brief information for the irradiation test

Irradiation period	2015. 10. - 2017. 9.
Estimated burnup	~25 GWd/mtU
Test rig # in HALDEN reactor	IFA-790

Table 2. Specifications of prepared pellet samples

	Ceramic micro-cell pellet	**Metallic micro-cell pellet**
Cell wall materials	0.6 wt% Si-Ti-O (2 vol%)	3.4 wt% Cr (5 vol%)
Averaged cell size* (μm)	~80	~290
Pellet density (g/cc)	10.73±0.03	10.45±0.03
Pellet diameter** (mm)	8.190±0.002	8.196±0.001
Pellet height (mm)	9.4±0.2	9.12±0.03
Pellet weight (g)	5.15±0.10	4.93±0.02
U enrichment	4.5%-U^{235}	4.5%-U^{235}

* A ceramic micro-cell consists of one grain. Therefore, the cell size of a ceramic micro-cell pellet is equal to the grain size. On the other hand, a metallic micro-cell consists of a lot of grains (6-7 μm).

** Pellet diameter after centerless grinding process.

3. Summary

To investigate the irradiation behaviors of the micro-cell UO_2 fuel pellet materials, a HALDEN irradiation test is planned for two kinds of micro-cell UO_2 pellets. Two kinds (ceramic and metallic) of micro-cell UO_2 pellets were prepared.

The in-situ data of irradiated micro-cell UO_2 pellets are expected to be obtained, and the progress of the irradiation testing continuously reported. Through the irradiation test and post-irradiation examination, the designed fuel performances of the micro-cell UO_2 fuel pellets will be verified.

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