Characterization of Additive-Doped UO_2 Pellets with Thermal Annealing Tests

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1. Introduction

The development of fuel pellets for LWRs has been focused on increasing the economic efficiency of the nuclear power generation through the efforts such as, increasing the fuel discharged burn-up, extending the fuel cycle, and up-rating the maximum power. However, the technical issues of the high burn-up fuels and the related operating conditions are to make the probability of PCI(Pellet Cladding Interaction)-related fuel failure higher. In order to mitigate the issue, PCI improvements can be achieved by enlarging the pellet grain size. A grain size enlargement of the fuel pellet is expected to enhance fuel plasticity at an elevated temperature of transient operation as well as the fission gas retention capability which is also an important feature of nuclear fuel pellets.

Korea Atomic Energy Research Institute (KAERI) has been developing the additives doped large grain UO_2 pellets for PCI remedy [1, 2]. We have designed several additives system for UO_2 pellets and investigated the properties of the pellets. Recently, we have selected promising candidates and accomplished an irradiation test in HANARO research reactor. In order to investigate the effects of the selected additives on microstructural aspects of the pellets and fission gas retention capability, we have conducted microstructure analysis and a thermal annealing test for observing fission products release behavior.

In this study, we will present the microstructural analysis of non-irradiated pellets with the thermal annealing test. The characterization on the microstructures of the pellets, concentration and distribution of doped additives in the pellets will be provided. The result of this experiments and analysis is considered to be the basis for the analysis of the irradiated fuel pellets and designing pellets with PCI improvement.

2. Experimental and Result

In this section, the experimental methods and the results for thermal annealing test and fission gas retention test are described; the sample preparation, thermal annealing test apparatus, density and microstructural analysis of pellets with an optical and electron microscopy, and additive analysis will be presented.

2.1 Sample preparation

Four kinds of UO_2 pellets were prepared for the research. (see Table 1) First one is the standard UO_2 pellets(SA) having small grain about 10μm. Those pellets are reference pellets to compare fuel performance enhancement in the developed doped pellets. Second one is Mn+Al based oxide additive doped UO_2 pellets. The average grain size of the pellets is about 40μm. Last two are Cr-oxide additived doped UO_2 pellets(SC and SD). The grain sizes of those pellets are ranged from 30 to 75μm according to the dopant amount of the metal contents. The undoped and doped UO_2 pellets(SA-SD) were fabricated by conventional sintering process.

Table 1. Specification of sample pellets

ID		Additives contents (M/U, μg/g)		Grain size (μm)	Density (%)
SA	UO_2	None		9.3	97.3
SB	Mn-Al	Mn	1078	37.0	97.4
		Al	57		
SC	Cr-1	Cr	1135	30.0	97.6
SD	Cr-2	Cr	1703	73.9	98.0

2.2 Thermal Annealing Test

The purpose of thermal annealing test is to determine evolution of fuel and additive/dopant microstructure relevant to conditions for release of volatile fission product gases.

We have designed the test apparatus and Fig. 1 shows the conceptual drawing of test apparatus [3]. The apparatus consists of a furnace system and a glove box. The furnace system is equipped in a hot cell and the glove box is located at out-side of hot cell for the case of testing irradiated samples.

Two types of the thermal treatment were conducted for the annealing test, a threshold temperature test and an incubation time test. The heating/cooling rate for the two tests is 10°C/min, maximum temperature and holding time is 1600°C, 10min, and 1500°C, 2hrs, respectively.

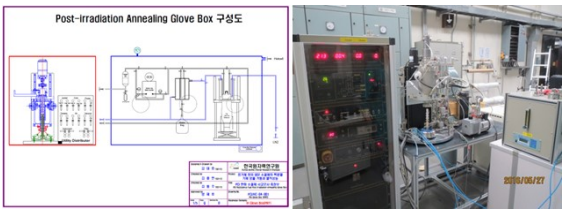

Fig. 1. The schematics and the photo of the thermal annealing test apparatus.

2.3 Microstructural Analysis

In order to investigate the change after thermal annealing tests, as-sintered pellets and the heat-treated pellets were characterized. The microstructure of pellets was characterized by optical microscopy and scanning electron microscopy (SEM). Three locations of center, middle, and periphery within each sample were selected for investigation. Through the optical microscopy, the pore number, pore size and pore area, grain size and distribution in an individual image were obtained and calculated by using image analyzer. Considering irradiated pellet samples can be fragmented during irradiation, we observed microstructures of the pellets fractured on purpose. Fig. 2 shows the microstructures of the pellets after the threshold temperature test. The characterized microstructural features of the pellets were compared between the fabricated conditions and also as the thermal tests.

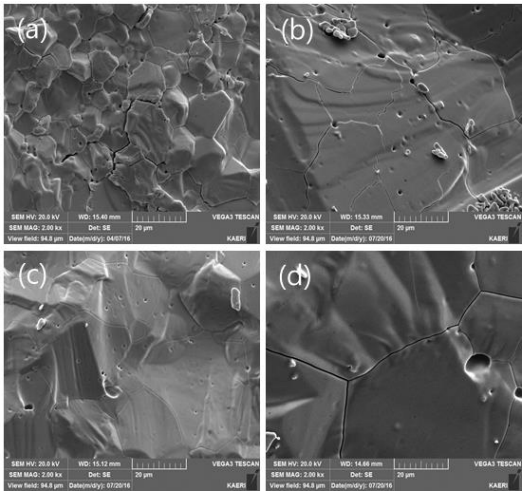

Fig. 2. The microstructures on a fractured surface of the pellets after the threshold temperature test. (a)-SA, (b)-SB, (c)-SC and (d)-SD.

2.4 Additive Contents Analysis

The distribution of additive elements and composition of specific inclusions were measured by using energy dispersive spectroscopy (EDS). EDS mapping has been applied to quantify the number of undissolved additive particles in a pellet within the three locations. The distributions of additive elements in the pellets and contents change after the thermal annealing test were investigated.

3. Summary

In this study, the microstructures and the dopants additives of non-irradiated pellets with the thermal annealing test were investigated. The details of characterization on the microstructures of the pellets, concentration and distribution of doped additives in the pellets will be provided in the presentation. The result of this experiments and analysis is considered to be the basis for the analysis of the irradiated fuel pellets and also for designing pellets with PCI improvement in near future.

ACKNOWLEDGEMENT

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