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An Investigation on the Release Behavior of Xenon Gas in Simulated Fuels under a 100% Helium Condition

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1. Introduction

To investigate the fission gas behavior of a dry process fuel, several experiments have been performed for various conditions with a simulated fuel. An annealing test had been done to trap xenon gas under a helium environment in the heater. In this test, a simulated fuel of a 60 GWd/t burnup was used to compare the results of low burnup fuels and fresh UO_2 fuels. The simulated fuel samples had been irradiated for several minutes in the IP hole of the HANARO reactor. And the ORIGEN-ARP code was used to estimate the activity of the irradiated fuel. A brief comparison of the diffusion coefficients of the simulated fuels and the previous data is given in this paper. Finally, some analysis results are also given for the different behaviors of various impurities in the simulated fuel.

2. Methods and Results

In this section the procedure of the experiment for a fission gas release for a simulated fuel is described.

2.1 Preparation of Simulated Fuel

To simulate the irradiated fuel, two kinds of simulated fuels are fabricated under the standard condition[1]. Table I shows the content of the impurities for the simulated fuels with a burnup of 30 GWd/t and 60 GWd/t.

Table I. Impurity Contents for Simulated Fuel (wt%)

Oxides	30 GWd/t	60 GWd/t
MoO_3	0.396	0.805
RuO_2	0.330	0.686
Rh_2O_3	0.042	0.063
PdO	0.108	0.268
TeO_2	0.047	0.099
$BaCO_3$	0.164	0.350
SrO	0.088	0.170
Y_2O_3	0.049	0.096
ZrO_2	0.392	0.780
La_2O_3	0.116	0.233
CeO_2	0.834	1.511
Nd_2O_3	0.526	1.076
UO_2	96.906	93.865

The sintered simulated fuels were fabricated in the sizes of a 2X2X2 mm cubic form to only consider the lattice diffusion of fission gas release. The simulated fuel considered in this test was a 60 GWd/t burnup fuel because it had been done previously for the simulated fuel of a 30 GWd/t burnup.[2]

The simulated fuel sample had been irradiated in the HANARO IP hole for 16 minutes only to find the lattice diffusion except for the pore effect and irradiation damage. The irradiated fuel had been cooled down for one week to reduce the radioactivity.

2.2 Pre-Calibration

To estimate the activity of xenon in the irradiated fuel, a calibration was done in an annular cylindrical geometry. During the calibration, the activities of I-132 (773 keV, 668 keV) and La-140 (816 keV) were measured with a Ge-detector. Using these values, the activity of Xe-133 was estimated by using an depletion code of ORIGEN-ARP.[3] The ORIGEN-ARP is an updated version of the exiting ORIGEN-2 and it provides a GUI environment. From the results, the burnup of the irradiated fuel was also obtained.

To obtain the calibration factor for a trapping geometry, a standard isotope source was chosen as Ba-133 which has a similar behavior as Xe-133. The calibration factor (f_c) was determined as

$$f_c = C_{Xe} / C_{Ba} \qquad (1)$$

where C_{Xe}, C_{Ba} are the detection counts for xenon and barium, respectively.

2.3 Annealing Test

After the calibration stage, the irradiated fuel sample was set in the heater and it was heated up to 1400 ^oC. As the temperature is held at 1400 ^oC, a Ge-detector detects the accumulating activity of a released xenon gas. The helium gas flows steadily with the released xenon gas. When a total of 6 points were measured with a Ge-detector, the heater temperature was increased up to 1467 ^oC, 1534 ^oC, and 1600 ^oC. At each temperature step, 6 points were measured with a holding temperature. Then the fractional releases were obtained as shown in Fig. 1.

Finally, apparent diffusion coefficients (D') were obtained from the linear fitting of the fractional releases based on the Booth model:

$$f^2 = C \cdot D' \cdot t \qquad (2)$$

where f is a fractional release, t is time, and C is a constant.

Fig. 2 shows the apparent diffusion coefficients for the simulated fuel and the results of previous experiments for the simulated fuel of a 30 GWd/t and the UO_2 fuel.

2.4 Discussion

The simulated fuel of a 60 GWd/t has much higher diffusion coefficient when compared to the simulated fuel of a 30 GWd/t and the UO_2 fuel. And the previous study of a simulated fuel of a 30 GWd/t and the UO_2 exhibited a similar behavior in the helium environment. Compared to the previous experiments, this behavior is quite different. In the previous study, the oxygen potential is low (90%He + 10%H_2) and it was found that the diffusion coefficient of the simulated fuel was less than that of the UO_2 fuel. This behavior may result from the impurity of the +3 ions in the simulated fuel. If the oxygen potential is high (100%He), the diffusion of a fission gas makes progress via a preferable uranium vacancy to a vacancy cluster of +3 ions.[2] Thus, there may be a reverse behavior as shown in this experiment. However we found that the stoichiometry is an important factor in a fission gas release. Thus, more additional experiments should be done for the simulated fuel to find the effects of the impurities and the stoichiometry.

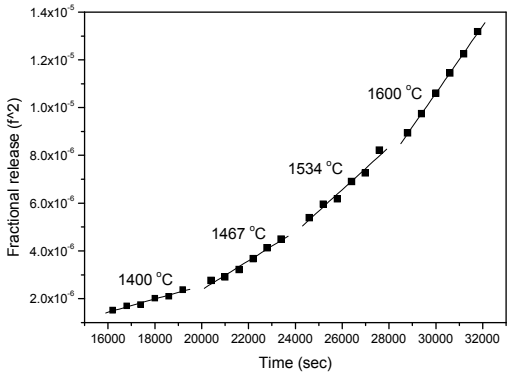

Figure 1. Fractional release for simulated fuel

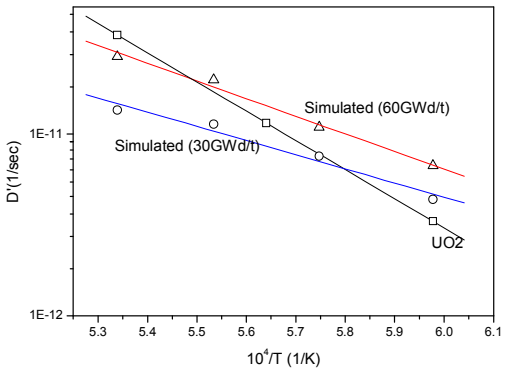

Figure 2. Apparent diffusion coefficient for simulated fuels

3. Conclusion

Fission gas release experiments with a simulated fuel have been performed to establish the fission gas behavior of dry process fuel. It was found that the diffusion coefficient of the simulated fuel increases as the impurity contents increase. But there are many unresolved problems regarding the fission gas release of a simulated fuel in terms of the impurity contents and stoichiometry. As a conclusion, it is believed that it will be very fruitful for a fuel performance if we reveal the effects of the impurity and the stoichiometry of a simulated fuel on the fission gas release.

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