Behavior of Xenon Diffusion in Irradiated UO_2 as Grain Size and Porosity

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1. Introduction

Xenon, which is generated by fission in UO_2, is released from a UO_2 pellet. The release of xenon has been studied with the diffusion in a solid. The diffusion of xenon is controlled by the stoichiometry of UO_2, the irradiation effect, and the valence of fission products as well as temperature[1]. In the case of the grain size effect, release rate of xenon is different. In this study, a PIA test(post-irradiation annealing test) with different grain sized UO_2 samples was carried out to observe the fractional release at high temperatures[2,3].

2. Experimental

2.1 Annealing apparatus

The system used for the PIA test was installed in an IMEF (Irradiated Materials Examination Facility) and consists of a furnace, filtration and detector as shown in Fig. 1. The furnace used was an electric resistance type with a super kanthal heat source. This can be raised up to 1600 ^oC. In addition, a zirconia oxygen sensor was also installed. As the carrier, helium(mixed with 10% of hydrogen) gas was able to transport xenon gas into the cryogenic filtration system well. The filtration system was made using charcoal contained in a pyrex glass chamber. The chamber was placed in liquid nitrogen to catch xenon gas as a solid adsorption.

A lead box covered the filtration system and a gamma detector was attached to count the released Xe-133 gamma rays. The detector was a semi-conductor type HPGe(high purity germanium) and cooled down by liquid nitrogen.

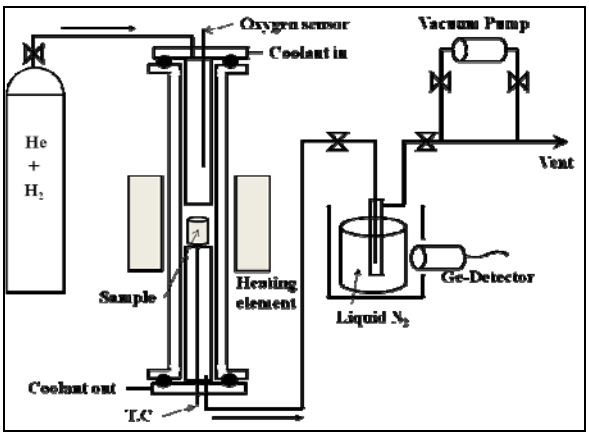

Fig. 1 The apparatus for PIA test (IMEF)

2.2 Sample preparations

The fuel samples were made using natural uranium and 12 samples with 4 different grain sizes were prepared as shown in Table.1. the shapes and microstructures were shown in Fig.2 and Fig. 3. All samples including two pure UO_2 samples were a disk type 4.5-4.7 mm in dia. and 1.4-1.6 mm thick.

Table 1 Sample properties

Index	Thick. (mm)	Dia.(mm)	Weight (g)	TD(%)	Grain size (㎛)
10F-17U	1.479	4.757	0.266	95 ~ 96	
10F-18U	1.810	4.717	0.325	95 ~ 96	6
10F-19U	1.634	4.747	0.295	95 ~ 96	
10F-20U	1.662	4.709	0.300	95 ~ 96	
10F-21U	1.562	4.732	0.288	95 ~ 96	15
10F-22U	1.603	4.722	0.294	95 ~ 96	
11F-13U	1.45	4.92	0.2400	92.7	
11F-14U	1.32	4.93	0.2333	92.7	25
11F-15U	1.38	4.83	0.2330	92.7	
11F-16U	1.61	4.87	0.2771	94.4	
11F-17U	1.55	4.87	0.2741	94.4	40
11F-18U	1.56	4.81	0.2684	94.4	

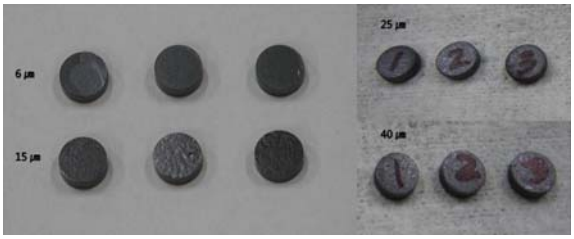

Fig. 2 Sample shape(Disk type)

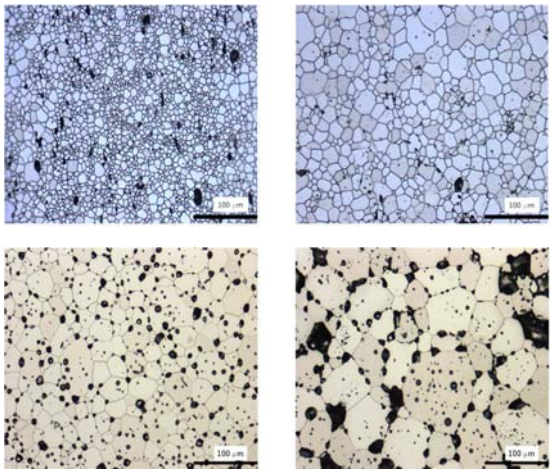

Fig. 3 Microstructures of each grain size

After irradiation for 16 minutes in the HANARO reactor, the sample tube was dismantled and the sample was contained in an Al_2O_3 crucible for loading into the furnace for the annealing test.

2.3 The annealing procedure

To obtain the radioactivity of the released and generated Xe-133, standard source, Ba-133 was detected at the same geometry of Xe-133 due to its gamma energy(81 keV), which was the same as Xe-133. Before the annealing, the total gamma scanning for the Al_2O_3 crucible was carried out to obtain the radioactivity of Xe-133 in the irradiated fuel sample. An ORIGEN-2 code was used to obtain the burnup and generation of Xe-133. Annealing was performed at 1400 ^oC for 13 hours, 1500 ^oC for 9 hours, and 1600 ^oC for 6 hours, continuously. The gamma detector was activated in filtration every 3600 sec. and the released Xe-133 peaks were obtained in all temperature ranges. The carrier gas ($He+H_2$(10%)) flowed at 0.1 l/min. and transferred the released Xe-133 into the filtration system.

3. Results

The fractional release of Xe-133(f^2) was plotted according to time for every sample. The slope of each temperature in each plot was used to obtain the diffusion coefficient of Xe-133.

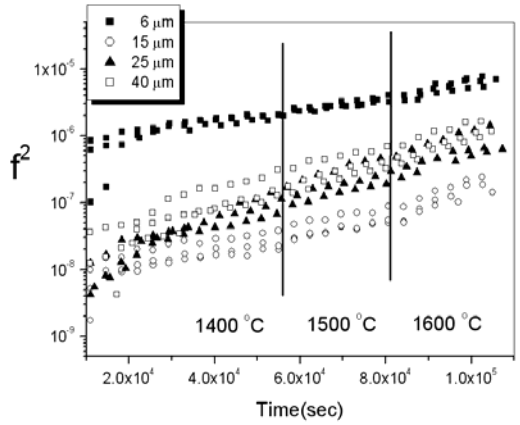

Fig. 4 Fractional release with annealing time

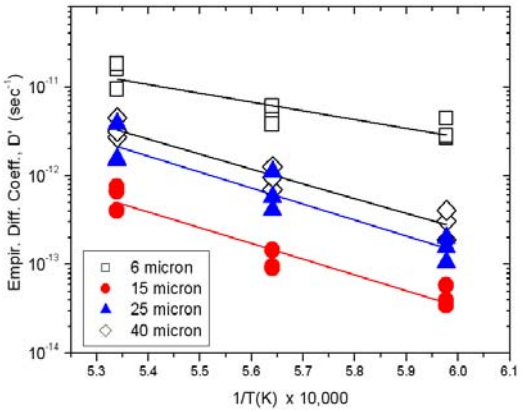

Fig. 5 Diffusion coefficients at each temperature($D'=D/a^2$)

4. Conclusions

Generally, xenon gas release in large grained sample is slower than in small one. The results of 6 and 15 ㎛ were reasonable but 25 and 40 ㎛ were higher than 15 ㎛. It seems to be considered with porosity effect.

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