Measurement of the Thermal Diffusivity of UO_2 using a Sapphire Tray for PIE in a Hot-Cell

Heemoon Kim, Dae Gyu Park, Sang Ho Na, Chang Je Park, Kweon Ho Kang, Yoo Byung Ok, Kim Gil Soo, Sang-Bok Ahn

Korea Atomic Energy Research Institute, 150 Deokjin-dong, Yuseong, Daejeon 305-353, Korea
hkim1211@kaeri.re.kr

1. Introduction

Thermal conductivity of an irradiated UO_2 is an important parameter to estimate thermal analysis of the UO_2 pellet in an operating reactor. It would decrease with burnup due to fission products and mechanical property changes.

A thermal conductivity consists of thermal diffusivity, density and specific heat. Specially, the first one has the more dominant effect. In this study, we focused on diffusivity measurement of irradiated UO_2. To measure thermal diffusivity, a LFA(Laser Flash Apparatus) was introduced.

The LFA in our facility(IMEF) is a vertical laser type, so the laser contacts on the bottom of the sample(disk type). A standard sample holder(3-tipped) was recommended to reduce the contact area with the sample in this laser type.

Those geometries in our LFA made it difficult to load an irradiated UO_2 sample to a standard holder because the sample had many cracks and it could have been broken during the test. So, we made a special holder and tray to solve this problem. The holder and tray were verified and tested with a fresh UO_2 sample to find any interference effects.

2. Experimental

2.1 Apparatus

The LFA consists of a laser generator, a furnace, an IR detector (In-Sb semi-conductor) and a controller. It was set up in a cold lab in IMEF temporarily, but later installed in a glove-box. The resonance material for the laser is Nd:YAG. The laser capability is 1.064 μm of wavelength and 40 J of a pulse energy[1]. The furnace can be heated up to 2,000 ℃.

The sample chamber was vertical type and laser contacts bottom of sample with upside emission as shown in fig.1.

2.2 Sample preparation and holder design

The sample was made by UO_2 which had about an 8 mm diameter and a 1.9 mm thickness as well as a 98% TD with natural uranium. The standard holder was made by high-pure alumina with 3-tips for sample loading and the cap was SiC. This standard holder was useful for the cold test but not for the hot test because it is not convenient for a sample to be loaded on a holder by special tools in a hot-laboratory. A high burnup UO_2 sample could drop through a crack under the test. As shown in Fig.2, a new holder and sapphire tray were made for an easy-loading sample.

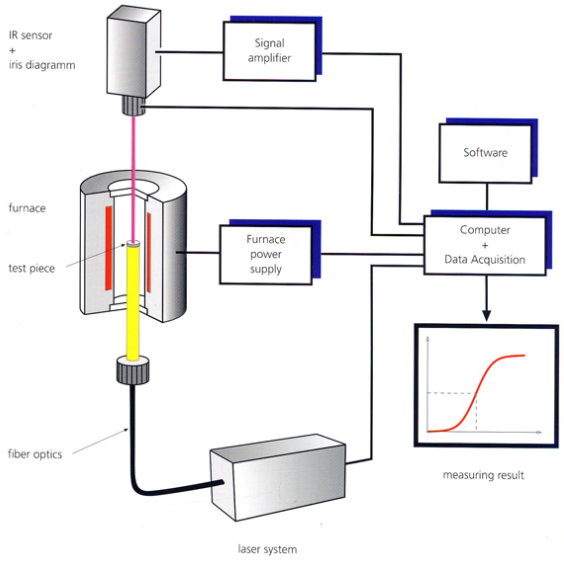

Fig. 1 The LFA(vertical type) in IMEF

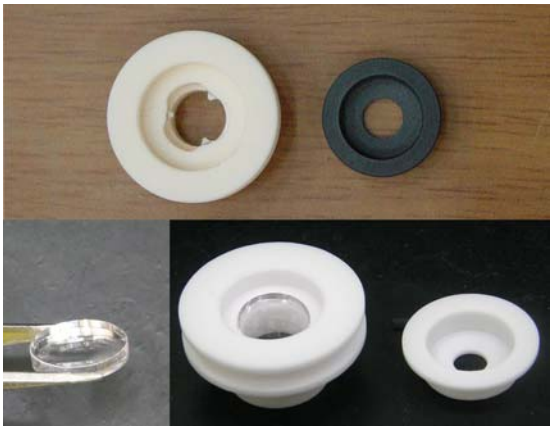

Fig. 2 Sample holders (top : standard holder, bottom : new holder with sapphire tray)

Sapphire has a high melting point(2,000℃) with no optic effects by laser treatment. Also, the sapphire tray was concave-shaped so as to reduce the sample contacting area.

2.3 Procedure and measurement

A UO_2 sample was loaded to a furnace and heated up to 1,600℃ with a flowing argon atmosphere. Thermal diffusivities were measured three times every 100℃. A laser voltage and a pulse time were 450 V and 0.6 ms, respectively. The applied model was the Cape and Lehman model[2].

3. Results

The diffusivity measurement with the LFA in IMEF is controlled by an inert gas state, not a vacuum state. To know the difference between the vacuum state and the flowing argon atmosphere, a data comparison must be carried out.

Fig.3 shows the data with the standard holder and the argon atmosphere and the reference data with the vacuum state[3]. It was almost the same regardless of the difference in porosity.

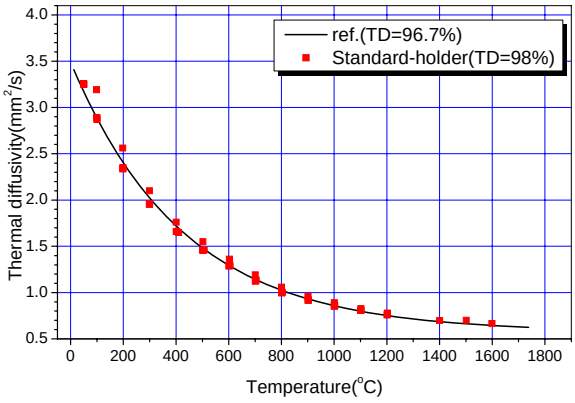

Fig. 3 Comparison of thermal diffusivity with the reference data and UO_2 with the standard holder

As shown in Fig.4, data with the new holder was higher than those with the standard holder. It seems that a sapphire tray effect occurred by a factor of 1.2~1.4.

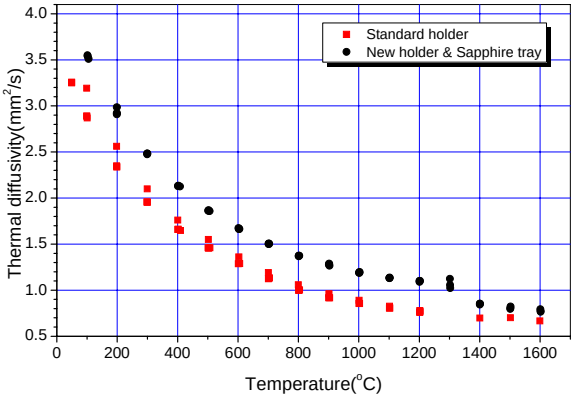

Fig. 4 Thermal diffusivities with standard and new holders

The three data at high temperatures in the new holder were lower than the curve line. The discontinuity would be from the smallest aperture of IR detector.

4. Conclusion

To know the effect of atmosphere, the data of UO_2 with the standard holder in the argon atmosphere showed good agreement as compared to the reference data. But, the thermal diffusivities with the new holder were larger than those with the standard holder due to the sapphire tray. When temperature increased, the difference increased gradually. The effect of the sapphire tray showed a factor of 1.2~1.4 with this standard holder.

REFERENCES

[1] LFA-427 manual, NETZSCH company.(2007)
[2] J.A.Cape, G.W.Lehman, 'Temperature and Finite Pulse-Time Effects in the Flash Method for Measuring Thermal Diffusivity.', Journal of Applied Physics, vol.34 1909p.(1963)
[3] M.Hirai,"Thermal Diffusivity of UO_2-Gd_2O_3 pellets", J. Nucl. Mater., **173** , 247-254(1990)