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Density Measurement of Silicon Carbide Layers of Simulated Coated Particles by Using a Density Gradient Column

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1. Introduction

The TRISO-coated fuel particle for a HTGR(high temperature gas-cooled reactor) is composed of a nuclear fuel kernel and outer coating layers. The coating layers consist of a buffer PyC(pyrolytic carbon) layer, inner PyC(I-PyC) layer, SiC(silicon carbide) layer, and outer PyC(O-PyC) layer[1,2]. The SiC coating layer acts as the primary barrier to the release of metallic fission products as well as fission gas and iodine. The density of SiC layer is one of the most important material properties for evaluating the soundness of SiC layer. The SiC fragments are acquired by oxidizing the broken coated particles. The SiC fragments are so small and irregular that it is not easy to measure the weight and volume of the SiC fragments. Density gradient column and standard floats can be used to measure such a small fragment[3-5]. X-ray radiography is one of the alternatives to measure the density of coating layer[6]. It is very difficult to calibrate the density by using the X-ray image. In this study, the densities of the SiC specimens of simulated TRISO-coated particles with ZrO_2 kernel were measured by a density gradient column with a density gradient solution.

2. Density Gradient Column

The model of the density gradient column used for this study is DC/02 made by LLOYD Instruments Ltd. as shown in Fig. 1(a). The density gradient solution should be made in consideration of the density of the sample to be measured. The density of SiC layer is often greater than 3.18 g/cc. We tried to make a solution with density gradient ranged from 3.10 g/cc of lower density to 3.30 g/cc of higher density.

Fig.1. A density gradient column to measure the density of SiC coating layer of coated particles.

100 cc of the lower density solution was made by mixing 50 cc of Bromoform and 50 cc of Diodomethane. Here, the density of Bromoform is 2.90 g/cc and the density of Diodomethane is 3.30 g/cc. 100 cc of the lower density solution is poured into a flask connected to an outlet to the density gradient column. 100 cc of Diodomethane is a higher density media, which is poured into the other flask connected to the flask with the lower density solution as shown in Fig. 2. Some of the higher density liquid flows into the flask with lower density solution by turning on the interconnecting tap between two flasks. Then density gradient solution is made by opening the outlet tap until there is a continuous unbroken flow of liquid through the filling tube in the density gradient column.

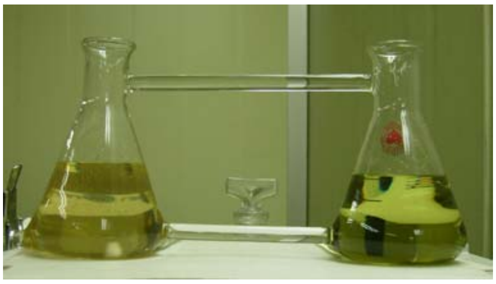

Fig.2. A flask with the lower density solution in the left side and a flask with the higher density liquid in the right side to make a density gradient solution.

The density range of the density gradient solution can be evaluated by using standard floats as shown in Fig. 3. The densities of the used standard floats were 3.15 g/cc, 3.20 g/cc and 3.25 g/cc, respectively.

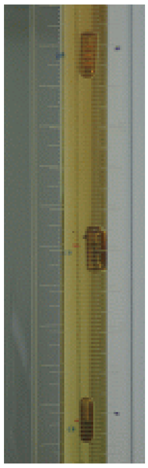

Fig.3. A gradient density solution for density measurement of SiC coating layer of coated particles.

The density D_x of the sample is calculated by equation (1).

$$D_x = a + \frac{(x-y)(b-a)}{(z-y)} \quad (1)$$

Where a and b are the densities of the two standard floats, which are at distance y and z from the arbitrary datum and x is the distance of the unknown from the same datum, intermediate between y and z.

3. Density measurement of SiC layer

SiC fragments should be prepared to measure the densities of them from the simulated TRISO-coated particles with ZrO_2 kernel instead of UO_2 kernel. The fragments of the broken coating layers consist of SiC layer and PyC layer. The PyC layer was removed from the SiC layer by oxidizing the fragments at the temperature of 850°C for 3 hours in the oxidation furnace. The prepared test samples were put in the density gradient solution of the column. The positions(x) of 4 specimens were measured after some time to come to equilibrium as shown in Fig. 4. The densities of the specimens were 3.199 g/cc, 3.197 g/cc, 3.202 g/cc and 3.205 g/cc, respectively by the variation of the position of each specimen as shown in Table 1. The average density of the samples was 3.201 g/cc.

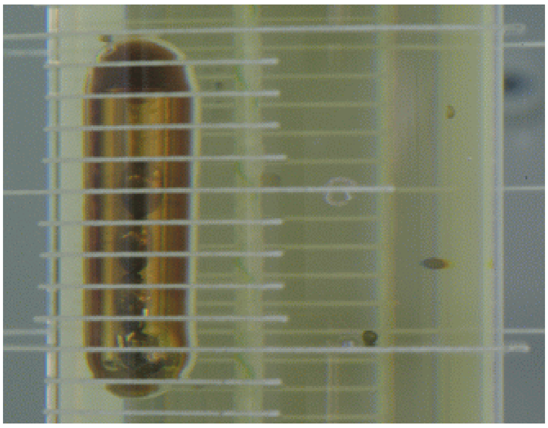

Fig.4. Standard float and SiC fragments floated in a density gradient column.

Table 1. SiC fragments floated in a density gradient column.

Specimens	1	2	3	4	Average
Density (g/cc)	3.199	3.197	3.202	3.205	3.201

4. Conclusion

In this study, the density of SiC layers of coated particles was measured by a density gradient column with a density gradient solution. The experimental results are as follows.

- The density gradient solution ranged from 3.10 g/cc of lower density to 3.30 g/cc of higher density was made by mixing Bromoform and Diodomethane in a density gradient column.
- Test fragments were prepared from the simulated TRISO-coated particles with ZrO_2 kernel instead of UO_2 kernel.
- The positions of 4 specimens were measured after some time to come to equilibrium.
- The densities of the specimens were 3.199 g/cc, 3.197 g/cc, 3.202 g/cc and 3.205 g/cc, respectively. The average density of the samples was 3.201 g/cc.
- The measured SiC density was higher than the low limitation, 3.18 g/cc, for the SiC layer of the TRISO-coated particles for the HTGR.

Acknowledgement

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