Evaluation of Coated Layers of HTGR Nuclear Fuel Particle

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1. Introduction

Recently, coated nuclear fuels have been attracted attention for their application of a high temperature gas cooled reactor for hydrogen production.[1, 2]The coated fuel consists of three types of graphite layers and one silicon layer on the spherical uranium oxide or uranium carbide fuel. In case of tri-isotropic (TRISO) coated fuel particles, the layers are low-density, porous pyrolytic carbon (PyC) buffer layer adjacent to the spherical uranium oxide fuel kernel, followed by an isotropic inner PyC layer, a silicon carbide layer and dense outer PyC layer.One of the problem of the coated uranium oxide fuel under the irradiation condition is so called "Amoeba Effect", which is the phenomena occurring the unidirectional movement of particle fuel kernel and eventually destruction of coated fuel [4]. Lots of investigations about the Amoeba effect have been carried out.The fuel performance under irradiation condition significantly depends on fabrication condition [5]. There are lots of study about performance of coated fuel, however, most of their study has been oriented to the failure probability of the coated fuel on the point of physics, nuclear engineering and mechanical engineering. Hence, in this study coated layers of TRISO type fuel were evaluated by field emission scanning electron microscopy and nano-indentation method to estimate "Amoeba effect" and give an optimum fabrication condition and high quality control.

2. Methods and Results

TRISO type coated fuel was fabricated by conventional fluidized bed type chemical vapor deposition (FBT-CVD) unit at the temperature range of 1200-1800 C°.[2] Source and carrier gases for the graphite and silicon carbide coating are propane, trimethychlorosilane and argon gas, respectively. The micro-hardness of each coated layer was determined by nano-indention technique (Micro-photonics NHT). Microstructure observation were carried out by field emission scanning electron microscopy (Jeol JSM 6700F) and scanning electron microscopy (Jeol JSM 35C), respectively. Fig. 1 is the shape of coated fuel and its cross sectional view observed by scanning electron microscopy (Jeol JSM 35C). The coated fuel is not perfect spherical shape, in which fuel kernel, buffer PyC, inner PyC, SiC and outer PyC layers were well observed. Average thicknesses of the coated layers are 95, 25, 30 and 28 μm, respectively.

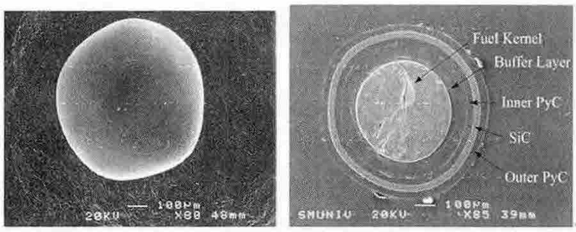

Fig. 1 Typical shape of coated fuel and the cross sectional view of the fuel

Fig. 2 is the microstructure of the coated layer and density of the coated layers. As shown in Fig. 2, buffer PyC layer porous structure and the porosity decreases in the order of inner PyC, outer PyC. The SiC layer has dense structure. Table 1 is the density and hardness of the coated layers. As shown in Table 1, hardness of PyC depends on its density. OPyC is the highest hardness value of 2.726 GPa among the PyC layers, which is well agreement with the results of microstructure observation in Fig. 2. The hardness of the SiC layer is 9.641 GPa, which shows the similar value of the SiC formed by chemical vapor deposition.[6] The density of the SiC is 3.18 g/cm^3, which is well agreement with previous result. [7] The densities of pyrolytic carbon layers increase in the order of buffer, inner, and outer PyC layers like the values of 1.08, 1.15 and 1.82 g/cm^3. As shown in Fig. 2, the lower density of the PyC layers is more porosity in the layer. Comparing theoretical density of pyrolytic carbon of 2.22 g/cm^3 [8], the relative amount of porosity in each layer is about 52 % for buffer, 48 % for inner PyC and 18% for outer PyC.

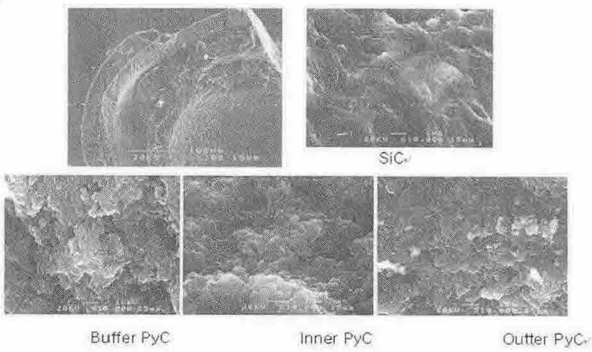

Fig. 2. Microstructure coated layers

Table 1. Density and hardness of coated layers of oxide fuel

	Density [g/cm3]	Hardness [GPa]
Buffer PyC	1.08	0.522
Inner PyC	1.15	0.874
SiC	3.18	9.641
Outer PyC	1.82	2.726

3. Summary

Simulation Coated layers of a nuclear fuel particle were evaluated by field emission scanning electron microscopy and nano-indentation method to give basic data to estimate "Amoeba effect" and give an optimum fabrication condition and high quality control. Coated layers on the fuel kernel are in the order of buffer pyrolytic carbon, inner pyrolytic carbon, silicon carbide and outer pyrolytic carbon layers, which average thicknesses are 95, 25, 30 and 28 μm, respectively. Their densities and hardnesses are 1.08, 1.15, 3.18, 1.82 g/cm^3 and 0.522, 0.874, 9.641 and 2.726 GPa, respectively. Comparing theoretical density of pyrolytic carbon of 2.22 g/cm^3, the relative amount of porosity in each layer is about 52 % for buffer, 48 % for inner PyC and 18% for outer PyC.

Acknowledgement

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