Characterization of Carbon Nano-Particles from the Clad of Nuclear Fuel in HTGR with Inherent Safety(II) –Quantitative Analysis

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The carbon nano-particles generated in the He coolant of High Temperature Gas Reactor will be radio-activated by the irradiation of neutrons in nuclear reactor core, and they will cause severe radioactive contamination in the case of LOCA even in HTGR with inherent safety. In the previous experiment (Nishida, et al., 2013), a qualitative analysis of the carbon nano-particles generated from IG-110 carbon pebble, the nuclear fuel clad, was reported concerning the R&D on a passive removal system in the primary cooling system of HTGR or PBMR.

In this report, more quantitative analysis of the carbon nano-particles was carried out associated with SEM analysis on the morphological change of surface of IC-110 carbon plate and carbon pebble before and after the heating to make clear the generation mechanism.

Setup of the experimental system was same to that of Nishida, et al. (2013). The morphological change of the carbon surface was observed with SEM. Decrease of mass of the carbons due to the *worn-down* caused by heating was measured with an electronic force balance. The surface change of the carbon pebble is shown in **Fig.1**. The pictures were taken without any tilt, and lower acceleration voltage (3kV) was applied to avoid giving extra damage on the surface.

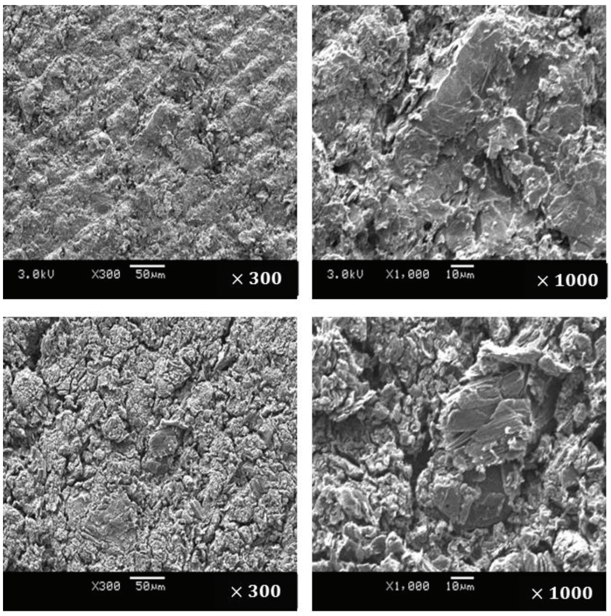

Fig.1 SEM pictures of carbon pebble (IG-110). Heating temperature was 1400K, and the pictures (upper two: before heating, lower two: after heating) were taken from the top view.

Figure 2 shows the same type of SEM picture for the carbon plate. In both cases, the roughness of the surface in lower magnification scale looked like to be smooth after heating. However, in higher one, clacking of the surface was observed clearly, especially in the plate. Sublimation of carbon will make the surface smooth, and the fragmentation or microscopic breaking due to heat shock will produce such type of clacking.

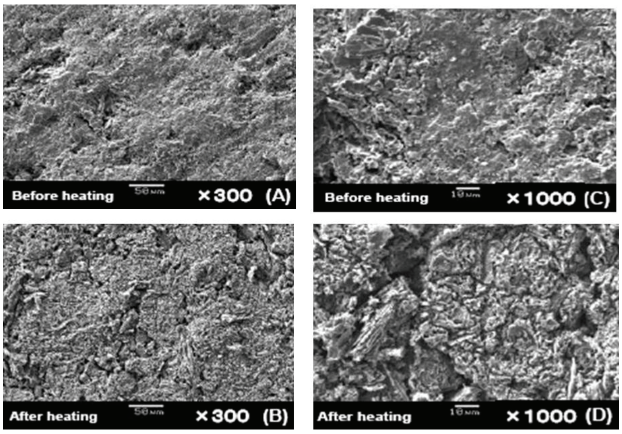

Fig.2 SEM pictures of carbon plate (IG-110). Conditions were same to Fig.1.

After 72 hours heating in the electric furnace at 1400K with continuous flowing of Ar gas, the average mass differences of carbon pebble and carbon plate by sublimation and/or fragmentation were 0.0383 g (4.11%) and 0.0089 g (5.1%), respectively. The mass of carbon vaporized from the carbon pebble set at continuous flow field of Ar gas was estimated theoretically to be 0.00797 g (less than 20% of the experimental value for mass reduction), and the difference between the experimental and the theoretical one will be the mass of generated fragments breaking from the pebble surface.

As shown in the qualitative analysis (Nishida, et al., 2013), the same conclusion was obtained that the major mechanism of carbon nano-particles generation in high temperature was not the homogeneous nucleation following the sublimation but the fragmentation caused by abrupt thermal shock. It provides us a clear design concept to R&D of the passive removal system in the primary cooling system of HTGR or PBMR, i.e., the main target diameter for reduction is about 10nm.

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