§33. Evaluation of Tungsten Coated Carbon as LHD Divertor Plate

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Tungsten seems a promising candidate material for the armor of the plasma facing materials such as the divertor plate in fusion devices because of its low sputtering yield and good thermal properties. The disadvantages of tungsten as the armor of the plasma facing components such as the divertor plate are its heavy weight and the brittleness below DBTT. For the near term application for LHD, tungsten coated carbon tiles could be convenient because the tiles could be easily replaced without big change in heat transfer properties to cooling channels.

Tungsten coatings on graphite by plasma spray (PS) or physical vapor deposition (PVD) were produced and their performance under high heat flux loading has been examined. Plasma sprayed tungsten coated materials are very useful as the tungsten armor of the high heat flux components because a coating rate is high and thick coatings of tungsten can be possible. Tungsten coatings on CFC and isotropic fine grain graphite have been successfully produced by vacuum plasma spray (VPS) technique and their good thermal and adhesion properties have been confirmed by high heat flux tests[1,2]. Furthermore, VPS-W coated CX-2002U and IG-430U were brazed on the OFHC with a cooling tube. Their thermal response on the mock-ups has been carried out under an actively cooling condition using electron beams[3]. In addition, surface modifications such as blistering and hydrogen isotope/helium retention of VPS-W irradiated by a low energy and high flux hydrogen isotope/helium have been also investigated[4,5].

Recently, higher density VPS-W coated CFC and isotropic fine-grained graphite compared to the previous one have been developed[6]. In the present work, VPS-W coated CFC and isotropic fine-grained graphite have been exposed to LHD divertor plasma to evaluate its performance for the LHD divertor plate.

Tiles (20mm x 20mm x 10mm) of carbon/carbon composite CX-2002U and isotropic fine grained graphite IG-430U made by Toyo Tanso Co. were coated with tungsten by vacuum plasma spraying technique(VPS). The thickness of the VPS-W layer was 0.5 mm and its density was 98% of the theoretical value. The VPS-W coated CX-2002U and IC-430U were mounted on the probe head. They were transferred to the divertor-leg position by using the retractable material-probe system equipped with the LHD, and then exposed to successive hydrogen discharges with magnetic axis of 3.75m and 3.6m. In the case of magnetic axis of 3.75m, the VPS-W coated tiles were exposed to successive 20 discharges of 2s (shot-#73474-73439, 40 s in total), by NBI heating (7.7 MW(2s), 5.1 MW(1s)). On the other hand, in the case of magnetic axis of 3.6 m, the VPS-W coated tiles were exposed to successive 23 discharges of about 2s (shot-#75747-75769, about 40 s in total), by NBI heating (3.5 MW(2s), 3.5 MW(1.5s)). Typical electron density(n_e) in core plasma and T_e($\sim T_i$) in the divertor region were 6-8 x 10^{19} m^{-3} and a few 10 eV. The temperatures of the VPS-W coated carbon tiles were monitored by thermocouples inserted to the carbon tiles of position of 2.5mm beneath from the surface.

After the exposure, surface morphology, microscopic damage and chemical composition were examined by means of scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS), respectively. In addition, chemical composition including in hydrogen has been examined by Rutherford Backscattering Spectrometry (RBS) and Elastic Recoil Detection(ERD) .

In the case of magnetic axis of 3.75 m, four lines were observed on the probe head along the divertor leg. The color of the four lines changed from metallic sliver to typically red and blue by the exposure. EDS analyses showed that C was included in the color change area. In addition, large amount of hydrogen also exists in this area. This four change area is considered to be re-deposited layer and corresponds to the divertor structure. Cracks on the surface and exfoliation between the joint interface of VPS-W and carbon on the VPS-W coated carbon tiles were not formed. On the other hand, in the case of magnetic axis of 3.6 m, footprint trace of divertor leg on a retainer plate made by tungsten seemed to be molten and re-solidified. However, macro and microscopic cracks were not formed on the VPS-W coated carbon tiles. These results indicates that the thermal and adhesion properties between the substrate and coatings were good under high heat flux by LHD divertor plasma.

1) K.Tokunaga, et.al.,J.Nucl.Mater.258-263(1998)998.
2) T.Tamura, et.al., J.Nucl.Mater.329-333(2004)687.
3) K.Tokunaga et.al., Fus. Eng. Des. 49-50(2000)371.
4) K.Tokunaga, et. al., J.Nucl.Mater. 313-316(2003)92.
5) K.Tokunaga, et. al., J.Nucl.Mater. 337-339(2005)887.
6) K.Tokunaga et.al., Fus. Eng. Des. 81(2006)133.