§7. Evaluation of Tungsten Coated Carbon as LHD Diverter Plate

Tokunaga, K., Fujiwara, T., Miyamoto, Y., Araki, K. (RIAM, Kyushu Univ.),
Tokitani, M., Masuzaki, S., Ashikawa, N.

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. Tungsten coatings on CFC (CX-2002U) and isotropic fine grain graphite (IG-430U) 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. 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.

Utilizing the findings of the above results, VPS-W coated IG-430U has been produced for LHD diverter and has been used as the diverter tiles of the first section in LHD from fiscal year 2008. Macroscopic damages such as crack and exfoliation have not occurred in the experiments so far. These results demonstrate that the VPS-W coated IG-430U has been withstood for use of the LHD diverter tile. The previous works have made a contribution of the development and production of the W coated carbon diverter tile of LHD.

In the present works, large scale size VPS-W coated CX-2002U, which has high thermal conductivity and good mechanical strength, has been produced experimentally. In addition, W coatings by atmosphere pressure plasma spray (APS), which is useful at maintenance and repair of the W coatings, have been produced.

It is well know that manufacture of large size W-coated CFC is difficult due to crack formation of W layer during the cooling after the coating by the difference of coefficient of thermal expansion with W and CFC, and orientation-dependent of CFC. Figure 1 shows VPS-W coated CX-2002U (VPS-W/CX-2002U) which is two dimensional CFC, has been produced experimentally. Sizes of substrate material CX-2002Us are 30mm x 60mm x 15mmt (left side) and 50mm x 60mm x 15mmt (right side). As shown in Fig. 1, three slits along 30mm or 60mm long suppresses crack formation due to relaxation of stress by the difference of coefficient of thermal expansion with W and CFC.

In addition, W coated material has been produce by APS and VPS to evaluate thermal property of APS-W. The substrate material is reduced-activation ferritic/martensitic steel (RAF/M) F82H (Fe-8Cr-2W). Size of the substrate material was 20mm x 20mm x 2.6mmt. A thickness of W is 1mm. Mock-ups were made by brazing the tiles (VPS-W/F82H, APS-W/F82H) on oxygen free high purity copper (OFHC) block with a cooling tube with a inside diameter of 7mmΦ. Heat load tests were performed on the active cooling test stand (ACT) of NIFS. Uniform electron beam at 30 keV was irradiated on the tungsten surface through a beam limiter with an aperture of 20mm×20 mm.

Fig.1 VPS-W/CX-2002U

Beam duration during ramp-up, plateau and ramp-down were 20, 40 and 0 s, respectively. Heat flux was changed from 1 to 3.4 MW/m^2. Thermal fatigue tests were also carried out for up to 100 cycles at a heat flux of 3.2 MW/m^2. Surface temperature of the tile is measured. Temperatures of F82H (T1) and OFHC (T2) of interface of brazed area were also measured with thermocouples. The heat flux tests have been carried out under the condition that the water flow velocity, pressure and temperature were 18.0 m/s, 0.7 MPa and 20 ^{o}C, respectively.

Figure 2 and Fig.3 show heat flux dependence of plateau temperatures measured at the surface, T1 and T2 for VPS-W/F82H/OFHC and APS-W/F82H/OFHC, respectively. It can be seen that the temperatures increased monotonically with increasing heat flux. Surface temperature of the VPS-W/F82H/OFHC is always lower than that of the APS-W/F82H/OFHC; for example, the surface temperatures are about 700 ^{o}C and 1200 ^{o}C at the heat flux of 3.4 MW/m^2, respectively. In the case of steady state, temperature increase is inversely proportional to the thermal conductivity. The thermal conductivity of plasma spray W depends strongly on its texture structure and residual porosity. Cross sectional observation of the APS-W shows that pores partially existed between W particles. This is one of the reasons for the high temperature increase of the W surface of APS-W.

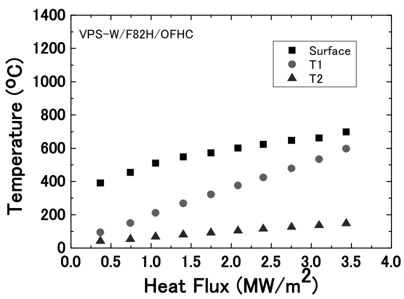

Fig. 2 Thermal response of VPS-W /F82H/OFHC

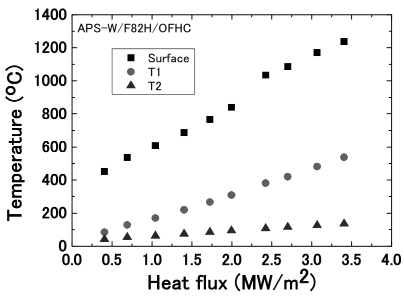

Fig.3 Thermal response of APS-W /F82H/OFHC