§17. Evaluation for High Z Divertor Plate Module of LHD

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LID divertor plate of LHD will be subjected to high heat flux of about 10 MW/m^2 and armor brazed with OFHC is going to be used as LID divertor plate. In this study, thick tungsten coatings on carbon carbon composite and other carbon materials for surface materials of the divertor was newly successfully demonstrated. High heat flux experiments have been performed on the coated tiles in order to prove the suitability and load limit of such coating materials.

Disadvantages of tungsten as a plasma facing material are its heavy weight and poor workability. One of the possibilities to overcome them is to coat tungsten on light carbon materials, which have shown good heat load resistance in the present plasma confinement devices. Thick tungsten coatings on carbon/carbon fiber composite (CFC) as well as isotropic fine grained graphite have been successfully produced. High heat flux experiments have been performed on the coated samples. In this present work, changes of composition and microstructure of joint interface between tungsten and carbon were examined in order to prove the suitability and load limit of such coated materials.

T iles, 20 mm x 20 mm x 10 mm, were coated by vacuum plasma spraying technique (VPS). The substrate materials were carbon/carbon composite CX-2002U and isotropic fine grained graphite IG-430U made by Toyo Tanso. The CX-2002U and IG-430U received PVD W/Re multilayer diffusion barrier layers* prior to the VPS tungsten coating in order to inhibit uncontrolled brittle carbide formation. The thickness of the tungsten coating layer was 0.5 mm and 1.0 mm. The samples were placed on a carbon/copper block actively cooled with water and were exposed by uniform electron beam. The duration of the beam was 20 s. The surface temperature of the sample was measured with an optical pyrometer. Before and after the irradiation, surface morphology, changes of microstructure and composition of the samples were examined with a SEM equipped with an EDS, EPMA and AES. Microhardness change of the W/Re mutilayer was also examined.

Fig. 1 shows a backscattered electron image(BEI) of the joint interface of the VPS-W and the carbon. This shows that tungsten was coated by the VPS after .the deposit of multilayers of Re and W. Composition analyses showed that the first tungsten layer includes about 34 at.% carbon. Owing to a temperature of heat treatment(1300 °C) after the coating, carbon is expected to diffuse to the first tungsten layer through Re layer from carbon materials. Microhardness tests showed that hardness of the layer is about 6 times harder than that of W. This indicates that tungsten carbide was formed in the layer. It is well known that activation energy for migration of carbon in tungsten carbide is higher than that of tungsten. On the other hand, the second W layer and thick VPS-W layer did not include such large amount of carbon. This indicates that the W/Re multilayer acts a diffusion barrier for carbon and suppresses the tungsten brittle carbide formation of the main tungsten layer(VPS-W).

The high heat flux tests showed that cracks on the surface and exfoliation between the joint interface of the sample were not formed below the melting point. These results indicated that thermal and adhesion properties between the substrate and coatings were good under high heat flux

Microstructure of the joint interface of the sample after the electron beam irradiation changed depending on temperatures. In the case of a peak temperature at about 2800 °C, the multilayer structure changed between the VPS-W and the first Re layer. Microcracks and exfoliation were observed in the layers. This is expected to be caused by brittle carbide formation due to the high temperature.

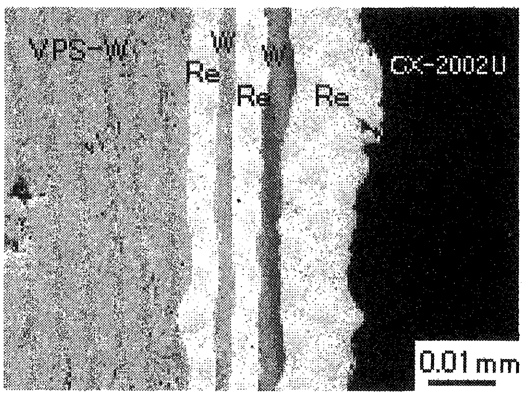

Fig. 1 BEI(Backscattered electron image) of the interface of cross-section of VPS-W coated CX-2002U(#6) with a tungsten thickness of 1mm.

* PVD W/Re multilayer diffusion barrier coating is patented by Plansee.