§35. 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.

Owing to its low sputtering yield and good thermal properties, tungsten seems a promising candidate material for plasma facing components in fusion devices but, tungsten is not easy to machine and weld. For technical realization of a tungsten material, tungsten coated carbon tiles can be envisaged. In this study, thick tungsten coatings on carbon carbon composite and other carbon materials were newly successfully demonstrated. High heat flux experiments were performed on the coated samples in order to prove the suitability and investigate behavior of gases emission and microstructure change by high heat load.

Tiles, 20mm x 20mm x 10mm, were coated by a vacuum plasma spraying technique(VPS). The substrate materials were carbon carbon composite CX-2002U, isotropic fine graphite IG-430U and molybdenum alloy TZM. The CX-2002U and the IG-430U received a diffusion barrier layer prior to the VPS coating in order to inhibit uncontrolled brittle carbide formation. Thickness of the tungsten coating layer were 0.5 mm and 1.0 mm.

A top surface of the sample was uniformly exposed to electron beam in Active Cooling Teststand(ACT) in NIFS. The heat loading time was 20 sec and the energy of electron beam was 30 keV. The heat flux experiments were performed by stepwise increase the power load. During the irradiation, the surface temperature was measured by a pyrometer and time evolution of vacuum pressure and electric current were monitored. Emitted gases and atoms from the heated specimen surface were also measured with a quadrupole mass spectrometer(QMS). In addition, surface morphology, microstructure and cross sectional composition of joint area between the tungsten and the base materials before and after the irradiation were observed by scanning electron microscopy(SEM) equipped with energy dispersion X-ray spectroscopy (EDS) and Auger electron spectroscopy(AES).

SEM observation of the surface of the VPS-W coatings showed that spherical particles were melted or partially melted and joined each other and pores were formed in the coatings. BEI(Backscattered Electron Image) and results of compositional analyses of joint interface of cross section of the VPS-W coated sample indicated that tungsten was coated by the VPS after deposit of the multilayer* of Re and W. This is expected to inhibit uncontrolled brittle carbide formation during use. No sign of delamination was seem.

Maximum surface temperature during irradiation increased linearly as a function of heat load below about 2500 °C. This is expected because condition of the sample was almost adiabatic and the radiation loss from the surface increased above 2500 °C compare with incident heat load.

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 was changed in the case of a peak temperature of about 2800 °C. A cross sectional observation indicated that the joint of the IG-430U and Re was good enough but structure of the multilayer was changed in the layer between the VPS-W and the first deposited Re, but tungsten carbide was not formed. This result indicates that Re layer sufficiently acts as diffusion barrier for carbon.

Many cracks and trace of melted tungsten flow were observed on the surface after melting and solidification. Large cavities were also formed in the inside of the resolidified tungsten layer. The multilayer structure was completely changed and new structure was formed, but crack between CX-2002U and metal was not observed. EDS analyses showed that carbon was not detected in the region newly formed.

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