

§8. Development and Evaluation of High Z Divertor Plate for LHD

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Divertor plate of LHD will be subjected to high heat and plasma particles with a low energy and a high flux. Tungsten seems a promising candidate material for surface material of the divertor plate because of its low sputtering yield and good thermal properties. 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 CFC and other carbon materials for surface materials of the divertor plate have been successfully demonstrated. High heat flux experiments indicated that the W-coated carbon tiles have good thermal properties. This year the W-coated CFC was exposed to high deuterium flux with a low energy (100 eV) to investigate surface modification and deuterium retention property.

Tiles, 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 made by Toyo Tanso. The CX-2002U received PVD W/Re multilayer diffusion barrier layers prior to the VPS tungsten coating in order to inhibit uncontrolled brittle carbide formation. Thickness of the tungsten-coating layer was 0.5 mm and 1.0 mm.

The facility used in the present experiments was the PISCES-B, which is a liner plasma simulator device at the University of California, San Diego. In the present experiments, working gas was deuterium. The sample was biased to be irradiated by ions. An energy of the ions on the surface was 100 eV. Ion fluxes to the sample were about 10^{21} to 10^{22} $\text{m}^{-2}\text{s}^{-1}$. The sample temperatures were 550 - 565 °C, which were measured with thermocouples and depended on the ion fluxes. After the plasma exposures, surface modification was examined with a Scanning Electron Microscope (SEM). Retention of deuterium after the exposure was examined by Thermal Desorption Spectroscopy (TDS). Weight loss after the exposure was also measured.

Samples used were the VPS-W coated

CX-2002U(VPS-W/CX-2002U). Pure tungsten fabricated by powder metallurgy (PM-W) was also used to compared with results of the VPS-W/CX-2002U. Surface of PM-W was electrically polished. The all samples were degassed by heating up to 1000 °C in high vacuum before installation to the plasma facility.

No modification was observed by the deuterium irradiation to a fluence of order of 10^{24} m^{-2} . However, blisters with a size of 0.1 - a few μm were formed on the surface of PM-W after the deuterium irradiation to a fluence of 7.50×10^{25} m^{-2} . The amount of blisters and their average size increased with an increase of a fluence to 3.00×10^{26} m^{-2} . In this case, the energy of deuterium ion was 100 eV. Therefore, displacement damage is not formed. In addition to this, range of deuterium with an energy of 100 eV is too small. The normal blistering formation mechanism is that blisters are formed near the end of range of injected gaseous ions due to bubbles formation by agglomeration of implanted gaseous atom and vacancy, which is formed by the displacement damage. Therefore, formation of these large blisters can not be explained by the normal blistering mechanism. Accordingly, one possibility is expected that large amount of deuterium was implanted and penetrated in to PM-W and caused the blistering by agglomeration.

On the other hand, in the case of the VPS-W, no modification such as blister was observed after irradiation to a fluence of 3.75×10^{25} m^{-2} . This reason for this results may be that surface is hard to modify and deuterium is hard to accumulate due to surface unevenness and pores near surface of VPS-W/CX-2002U.

The peak temperature of D₂ and HD released from PM-W, irradiated to a fluence of 7.5×10^{25} m^{-2} , was about 430 °C by TDS. This temperature is lower than that of the irradiation temperature. It may be that as the sample cools after the plasma exposure, the diffusing D atoms already in the PM-W can become trapped in sites that remain unoccupied during the higher temperature exposure. On the other hand, desorption curve of VPS-W/CX-2002U irradiated to a fluence of 3.75×10^{25} m^{-2} , gradually increased with increasing temperature up to 1000 °C and decreased at 1000 °C for 20 min. This may be due to trapping of deuterium the underlying carbon after diffusion through the tungsten layer. It is required to evaluate not only surface material but also substrate material because deuterium retention may be influenced by substrate materials due to diffusion.