§18. Elucidation of Mass Transport on Tungsten Plasma Facing Material by Surface Analyses

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Tungsten (W) will be planned to be used as the armor material of the first wall/blanket which is made of low activation materials such as reduced-activation ferritic/martensitic steel (RAF/M) of the fusion reactor because of its low erosion yield and good thermal properties. It is well known that the armor material is eroded by the ion sputtering and re-deposited layer is formed on the surface in the fusion plasma experimental devices. The re-deposited layer has complicated composition and structure which includes with oxygen. These influence hydrogen isotope retention, diffusion and permeation of the blanket, and the life time of the armor/low activation material. It is necessary that the behavior of the surface of the armor material is investigated. In the present works, behavior of the surface of W and other materials which were installed on vacuum chamber at LHD (NIFS) and QUEST (RIAM, Kyushu University) has been investigated to obtain guideline of development of the W armor of the blanket.

The VPS-W coated CX-2002U and IC-430U were mounted on a probe head. They were transferred to the diverter-leg position by using the retractable material-probe system equipped with the LHD, and then exposed to successive hydrogen discharges with magnetic axis of 3.75 m. 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)). Typical electron density(n_e) in core plasma and Te($\sim T_i$) in the diverter 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), Energy Dispersive Spectroscopy (EDS) and X-ray Photoelectron Spectroscopy (XPS), respectively. In addition, chemical composition including in hydrogen has been examined by Rutherford Backscattering Spectrometry (RBS) and Elastic Recoil Detection (ERD).

In addition, W, SUS316L and Au/SUS316L specimens have been installed on vacuum chamber at the first cycle on the spherical tokamak QUEST in RIAM, Kyushu University. After the plasma discharge experiments (September 2008 to January 2009), the specimens have been removed and have been investigated.

In the case of magnetic axis of 3.75 m at LHD, four lines were observed on the probe head along the diverter leg. The color of the four lines changed from metallic sliver to typically red and blue by the exposure. Peak temperature of the VPS-W coated tiles was at a relatively low temperature of 63 ^{o}C. This is considered to be that the heat flux is low because the area of long connection length was narrow. The XPS analyses showed that carbon(C) was detected on the surface layer. This means that the color change was due to the deposition on carbon. Figure 1 shows depth profiles of hydrogen on the color change and the non-color change area. The retention of hydrogen on the color change area is larger than that of the non-color change area and co-deposition with carbon and hydrogen occurred. In the case of LHD, carbon diverter tiles have been used. As a result, carbon, which was sputtered on the diverter tiles, came to the diverter area and deposited in the form of a lines on the VPS-W coated tiles with hydrogen, which was related with diverter structure.

On the other hand, in the case of QUEST, color change on the specimen surface uniformly occurred. The XPS analyses showed that carbon and oxygen exist on the surface. After the Ar sputter, carbon was detected. This shows that deposition layer of carbon was formed. The ERD analyses showed that hydrogen is retained on the carbon deposited layer. In the case of QUEST, SUS316L have been used as a vacuum chamber in QUEST. Therefore, residual gas such as hydrocarbon was decomposed by plasma discharge and carbon was co-deposited with hydrogen on the specimen surface of the vacuum chamber. The present results indicate that large amount of hydrogen may be retained in the deposited layer even if W is used as the armor material.

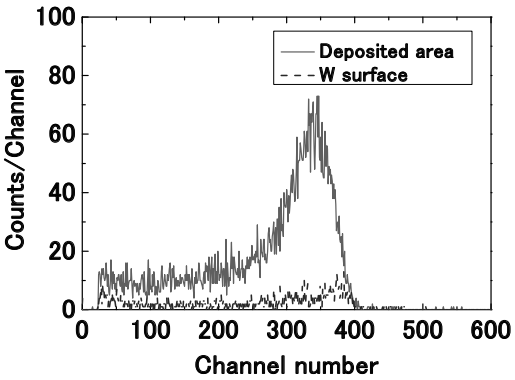

Fig. 1 ERD analyses on W surface of VPS-W coated carbon tile exposure by diverter plasma of LHD