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Deuterium retention behavior for tungsten exposed in LHD during the 18th plasma experimental campaign

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Abstract: Tungsten specimens were placed in the four positions of the plasma facing wall, namely PI (typical PWI area), DP (deposition dominated area), HL (higher heat load area) and ER (erosion dominated area) in the Large Helical Device (LHD) and were exposed to hydrogen plasma in the 18th experimental campaign. Microstructure and chemical composition of the specimens were analyzed by SEM, TEM and XPS. Additional deuterium implantation was performed for these specimens and their deuterium retention behavior was evaluated by TDS. Results showed that a carbon-dominated mixed-material layer was formed on the all of the specimens except for ER sample. The thickness of this layer has increased as compared with that of 17th experimental campaign. The major deuterium desorption temperature was correspondingly shifted toward the high temperature for DP and PI samples as well.

Keywords: LHD, Tungsten, Deuterium retention, TDS

1. Introduction

Tungsten (W), possess high energy threshold for sputtering, low ability to hydride formation and low hydrogen solubility level, has been selected as the most likely candidate of plasma facing materials (PFMs) for future fusion reactors [1]. However, it is well known that the irradiation damages and impurity layer will be inevitably formed on W in the actual fusion reactor. So, the investigations about the influence of damages and impurity layer on hydrogen isotope retention of W have been studied with interest using various heavy ion and ion irradiation, respectively [2]. For study the hydrogen isotope retention behavior in W exposed in plasma, the W specimens were placed in LHD and were exposed to long-term hydrogen plasma experiment. The deuterium retention behavior of the exposed W for the different LHD experiment campaign was systemically investigated [3]. Our previous works showed that the thickness of carbon-dominated mixed-material layer with impurities of oxygen and Nitrogen etc. deposited on W has increased year by year because of the usage of graphite in closed divertor to enhance the plasma performance. Additional deuterium ion implantation and thermal desorption spectroscopy (TDS) experiment results proved that the hydrogen isotope would be accumulated in this carbon-dominated mixed-material layer. In addition, the helium (He) desorption behavior has been observed for 2013 experiment campaign due to long-term He plasma discharge was performed to achieve high plasma performance. As the development of the system and the improvement of the plasma performance, the composition and microstructure of the surface impurity layer will be changed. So, we will continue to investigate the deuterium retention behavior for tungsten which was exposed in LHD during the latest (18th) experimental campaign in the present work.

2. Experimental

The mirror polished W samples with size of Φ10 mm × 5 mm were annealed at 1173 k for 30 min under vacuum circumstance and then were placed in the four unique positions of the plasma facing wall in the LHD. The sample labels are corresponding to their positions in LHD, which are named as PI, DP, HL and ER, respectively. After the hydrogen plasma experiment, the samples were picked up and transported to Shizuoka University with air exposure. Then, the 1.0 keV deuterium ion (D_2^+) were additionally implanted into these samples with the flux of 1.0×10^{18} D^+ m^{-2} s^{-1} and fluence of 5.0×10^{21} D^+ m^{-2}, respectively. The deuterium retention behavior of the samples was evaluated using the TDS with high resolution quadrupole mass spectrometer, which can distinguish the D_2 from He. Chemical composition and microstructure of the samples were examined by XPS, SEM and TEM.

3. Result and discussion

Figure 1 shows the D_2 TDS spectra for D_2^+ implanted tungsten exposed to LHD 18th experiment campaign. It can be seen that the major deuterium desorption of ER sample was located at low temperature less than 600 K. However, there are two deuterium desorption stages at higher temperature around 600-700 K and 900-1000 K for DP, PI and HL samples. As compared with that of 17th experimental campaign, the major deuterium desorption temperature was correspondingly shifted toward higher temperature for DP and PI. It was suggested that the deuterium desorption at temperature at around 900 k should be caused by desorption of deuterium which was trapped by thick carbon-dominated mixed-material layer as C-D bond. So, the surface carbon-dominated mixed-material layer should be an important factor on the deuterium retention enhancement on W, especially for the DP and PI area in LHD.

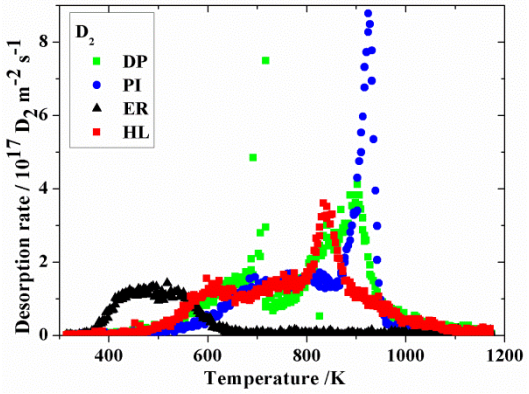

Fig.1 D_2 TDS spectra for D_2^+ implanted tungsten exposed to 18th experiment campaign

4. Reference

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