§3. Hydrogen Isotope – Materials Dynamics for Recycling Evaluation

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i) Introduction

In the future fusion reactor, tungsten will be used as a plasma facing material. One of the key issues for the usage of tungsten as a plasma facing material is the tritium retention evaluation under actual fusion conditions. In ITER, the tritium retention may be underestimated if the tritium retention in the impurity deposition layer is not considered. In addition, introduction of damages by energetic particles is also one of key parameters to determine the tritium retention. It is important to predict actual tritium retention in plasma facing materials. In our previous studies, the results of deuterium retention enhancement by 2011 (15th) plasma experiment campaign were shown 1). This paper presents the comparison of hydrogen isotope retention enhancement for tungsten exposed to plasma experiment campaigns in 2011 and 2012 at LHD.[2)]

ii) Experimental

The mirror finished disk-type tungsten samples with the size of 10 mm in diameter and ~ 0.2 mm in thickness were placed into in four typical positions, namely the higher plasma wall interaction area called as PI, the deposition area as DP, the higher heat load area as HL and erosion dominated area as ER. These samples were exposed to ~ 5000 shots for 2012 long-term plasma campaign. In 2012 campaign, the closed divertor structure, which consists of graphite parts, was installed in 8 sections to enhance the plasma performance, although that in 2011 campaign was 2 sections. Thereafter, the samples were picked up and transfer to Shizuoka University. The 1.0 keV deuterium ions (D_2^+) were additionally implanted into these samples with the flux of 1.0×10^{18} D^+ m^{-2} s^{-1} up to the fluence of 5.0×10^{21} D^+ m^{-2} to evaluate the enhancement of hydrogen isotope retention capacity. The hydrogen isotope retention was estimated by Thermal Desorption Spectroscopy (TDS). The Glow Discharge-Optical Emission Spectroscopy (GD-OES) was also performed to study the depth profiles of constituent atoms at University of Toyama. The microstructure was observed by Transmission Electron Microscopy (TEM) at Institute of Applied Mechanics, Kyushu University.

iii) Results and discussion

Table 1 summarized the results of H and D retentions for all the samples and surface characteristics in 2011 and 2012 long-term plasma campaign. It was found that the large hydrogen isotope retention enhancement was observed for all the samples. The carbon-dominated mixed-material layer was formed except for erosion-dominated area due to introduction of closed divertor where carbon was used. Most of hydrogen isotope was retained in this layer, which cause higher desorption temperature more than 800 K. More than 50 times of hydrogen retention enhancement for DP sample was derived compared to that for pure W. In especially, the carbon-dominated mixed-material layer would control the hydrogen isotope retention for all the area except for erosion-dominated area. In case of erosion dominated area, the desorption temperature was concentrated in the lower temperature less than 600 K, leading that most of hydrogen was retained in the irradiation damages of W. These results indicate that the chemical structure for carbon-dominant mixed-material layer may control H and D retention enhancement for most area except for erosion dominated area. For 2012 campaign, closed divertor was installed in 8 sections to enhance the plasma performance, although that in 2011 campaign was 2 sections, and ratio of graphite tiles in divertor region was clearly increased, leading the enhancement of carbon dominant mixed-material layer on most of the tiles and higher hydrogen isotope retention enhancement was found for 2012 plasma campaign sample even if the plasma shots were ~5000 shots.

1) Y. Oya et al., Fusion Eng. Des., 88 (2013) 1699.
2) Y. Oya et al., J. Nucl. Mater., 438 (2013) S1055.

Table 1 Summary of H and D retentions for all the samples and surface characteristics in 2011 and 2012 long-term plasma campaign.

	Pure W	PI		DP		HL		ER
		2011	2012	2011	2012	2011	2012	2012
H ($H\ m^{-2}$)	---	6.1×10^{20}	2.7×10^{21}	1.7×10^{21}	7.4×10^{21}	5.6×10^{20}	2.4×10^{21}	1.5×10^{21}
D ($D\ m^{-2}$)	1.4×10^{20}	3.6×10^{20}	6.4×10^{20}	1.3×10^{21}	3.0×10^{20}	3.2×10^{20}	9.7×10^{19}	8.1×10^{19}
Desorption Temperature	< 600 K	800-1000 K	700-1000 K	700-900 K	700-900 K	800-1000 K	700-1000 K	< 600 K
Surface characteristics	irradiation damage	thin deposition (0.3 μm)	thin deposition (0.5 μm)	thick deposition and rough surface (5.0 μm)	thick deposition and rough surface (6.0 μm)	thin deposition (0.1 μm)	thin deposition (0.2 μm)	very thin deposition (almost no deposition)
Retention enhancement	--	6.9	24	21	55	6.3	18	11