§14. Comparison of the Wall Pumping Capability of the Modified First-wall Surface of LHD during a Helium Long Pulse Discharges

Tokitani, M.,
Kasahara, H., Yoshimura, Y., Motojima, G., Sakamoto, R., Masuzaki, S., Ueda, Y., Sakamoto, M., Shoji, M., Mutoh, T., Yamada, H., Takeiri, Y., LHD Experiment Group

Ultra-long-pulse helium discharge with ion and electron cyclotron heating (ICH + ECH) in the Large Helical Device (LHD) was achieved in a 48 min plasma (n_e ~1.2×10^{19} m^{-3}, $T_{i,e}$ ~2 keV) with an average heating power of 1.2 MW in in the fiscal year (FY) 2013 experimental campaign. The temperature of the first-wall surface during discharges remained at nearly room temperature. In such a long pulse discharge, although the electron density is kept quite stable, the wall pumping rate of helium by wall surface is dynamically changed during a discharge [1)]. The material probe experiment in the FY2013 experimental campaign, it was clarified that the mixed-material deposition layers composed of C (~98%) and Fe (~2%) were continuously formed on the plasma facing components (PFMs) during a long pulse discharges, and the layers can act as the effective trapping site of helium. Amount of the retained helium on the mixed-material deposition layer was linearly proportional to the thickness of the mixed-material deposition layers [2)]. In addition, retention amount of helium on the mixed-material deposition layer did not saturate even at around 10000s exposure time. The the retention rate of helium on the mixed-material deposition layer was calculated to be ~1.6×10^{16} He/m^2s. The global wall pumping capability of the mixed-material deposition layer can be considered if we assume that approximately 3/4 (inner, upper, lower) of the PFMs in the LHD (~548 m^2) are covered by the mixed-material deposition layer. As such, the total average retention rate can be calculated as ~1.6×10^{16} He/m^2s × 548 m^2 = 8.8×10^{18} He/m^2s. This value is close to the wall pumping rate from a calculation by the global particle balance model [1)].

In the FY2014 experimental campaign, additional material probe experiment was performed for confirmation of the reproducibility of the mixed-material deposition layer and its wall pumping capability, and confirmation of the input RF power (P_{RF}) dependence for a wall pumping characteristics. The selected discharges are summarized in table 1. Fig. 1 shows the thickness of the C and Fe deposition layer as a function of the exposure time from FY2013 and FY2014 experiment by Rutherford backscattering spectrometry (RBS) analysis. The deposition rate of the C impurity in FY2014 campaign (P_{RF} ~1.4MW) was almost three times as high as FY2013 campaign (P_{RF} ~1.2MW). The composition of the mixed-material deposition layer was ~98% of C and ~2% of Fe in both FY2013 and FY2014 case. There is no indication of the input RF power dependence for formation of the deposition layer. Fig. 2 shows the Cross-sectional TEM images of (a) FY2014 and (b) FY 2013 campaign for P_{RF}~1.4MW (9062s) and P_{RF}~1.2MW (9860s), respectively. By comparing between thickness data of the mixed-material deposition layer between Fig. 1 and Fig. 2, we can estimated a porosity of the C based mixed-material deposition layer. It was estimated to be ~25% and ~10% for FY2013 and FY 2014, respectively. The porosity of the FY2014 was drastically decreased from FY2013. From the thermal desorption spectroscopy (TDS) analysis and RBS data, the retention ratio of the helium on a C based mixed-material deposition layer in FY2013 and FY2014 are estimated to be He/C=0.04 and He/C=0.002, respectively. This means that ability of the helium retention on the mixed-material deposition layer in FY2014 was decreased to almost 1/10 compared with FY2013. The reason why such differences are obtained, is current open question. One of the possible reason is that the differences of the porosity of the mixed-material deposition layer could cause the difference of the trapping ability of the helium. We will try a further experiment for clarify the difference of the helium retention between FY 2013 and FY 2014.

P_{RF}	$T_{e,i}$	n_e	Exp. time
~ 1.4 MW	~2.9 keV	1.3×10^{19} m^{-3}	9062s
≥ 2.0 MW	2.4~3.0 keV	1.2~2.0 × 10^{19} m^{-3}	1619s

Table 1. Two types of discharge for the material probe experiment.

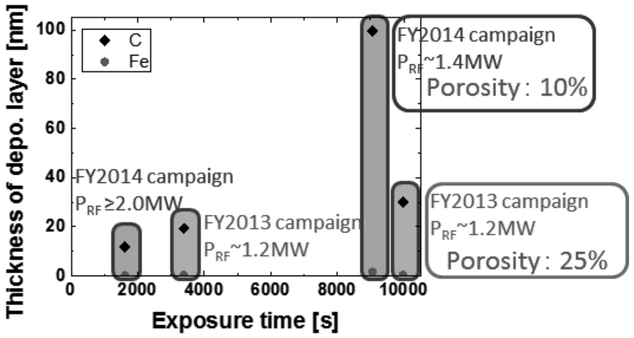

Fig. 1. Thickness of the C and Fe deposition layer as a function of the exposure time of P_{RF}~1.4MW case in FY 2013, and P_{RF}~1.4MW and P_{RF} ≥2.0MW case in FY2014 (RBS result).

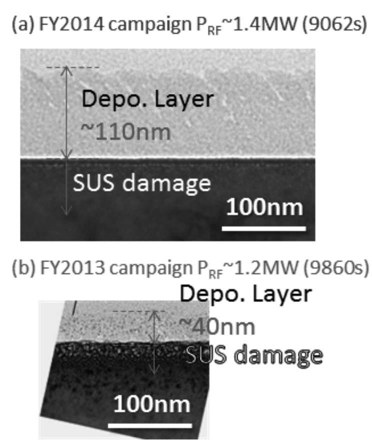

Fig. 2. Cross-sectional TEM images of (a) FY2014 and (b) FY 2013 campaign.

1) G. Motojima et al., J. Nucl. Mater. in press.
2) M. Tokitani et al., J. Nucl. Mater. in press.