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Material probe study for plasma facing wall of LHD

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Abstract

Impurity deposition and gas retention were investigated for material probes which were installed along toroidal and poloidal directions on plasma facing walls during the 4th experimental campaign in the large helical device (LHD). The carbon deposition was observed to be dominant on the surface of probes located far from the plasma. The retained amount of helium was also large in the probes located near the plasma, although that of hydrogen was large in the probe far from the plasma. The retained amounts of discharge gases and impurity gases were large near the anodes used for glow discharges, since the current density near the anode was large.

1. Introduction

It is quite important to know the wall condition of fusion devices and their changes arising from the progress of plasma experiments. For this purpose, the wall condition data have been systematically accumulated and characterized the wall through four experimental campaigns in the large helical device (LHD) since 1998. The wall conditions for the first and second experimental campaigns were reported in previous papers [1–3]. It was found that the performance of the LHD plasma was enhanced as the experimental campaign progressed due to adequate cleanings for the plasma facing wall [3] and the increase of input power. This paper presents the results obtained in the 4th experimental campaign.

From the first campaign to the 4th campaign, several material probes made by 316L stainless steel and isotropic graphite were installed along the poloidal direction at the same toroidal position of the inner wall. After the 4th campaign, the impurity deposition and the retained amounts of discharge gases and impurity gases in these probes were examined by auger electron spectroscopy (AES) and thermal desorption spectroscopy (TDS), respectively. The plasma surface interactions (PSIs) and the degree of wall cleaning were discussed based upon these analyses.

2. Experimental

In the 4th experimental campaign, there were a total of approximately 9000 shots of H_2 and He discharges. Before and after the experiments with main discharges, glow discharge cleaning using He or H_2 was conducted. From the 3rd campaign, graphite tiles were installed in the entire region of the divertor traces to reduce the emission of metal impurities from the wall into the plasma. The first wall material, 316L stainless steel, remained the same in all campaigns.

The locations of material probes along the poloidal direction at toroidal sector #7 are shown in Fig. 1(a). The size of each sample was $10\times20\times1$ mm. The samples, T-I and T-O, were placed at the inner and the outer divertor regions, L and U samples at the lower and upper first walls, and F-O samples at the port. In the 4th experimental campaign, material probes were also

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placed along the toroidal direction on the lower first wall as shown in Fig. 1(b). The poloidal position was at the lower first wall, the same as that of L in Fig. 1(a). In Fig. 1(b), the number of the toroidal sectors and the position of two anodes used for glow discharge are also shown. In every sample position, both stainless steel and graphite probes were placed in the sample holder. The stainless steel and graphite probes are useful to observe the deposition of carbon and metal impurities, respectively. In addition to these probes, stainless steel and graphite probes exposed only to the glow discharges or only to the main discharges were prepared in order to examine the PSIs during the glow discharges and the main discharges in the 4th experimental campaign. The positions of these probes were at the toroidal sector, #7.

After the 4th experimental campaign, the samples were recovered, and the depth profile of atomic composition and retained amounts of discharge gases and impurity gases were analyzed by AES and TDS, respectively.

3. Results

3.1. Impurity deposition

Carbon deposition was clearly observed on the stainless steel probes. The atomic composition depended significantly on the location of material probes. Fig. 2(a) and (b) show the depth profiles of atomic composition for the samples, L and T-O. The depth profiles for samples U and T-I were similar to that of sample L, although that for sample F-O was similar to that of sample T-O. The long tail of carbon depth distribution were observed in SS samples. The results means that on the SS probe not only carbon but iron atoms were deposited. Actually, metal impurity deposition was also observed on the surface of graphite probes. On the surface of the sample L, the carbon concentration was 60 at.% and the thickness of the carbon deposition was 30 nm. In the probe placed at the outer divertor, sample T-O, the carbon concentration was 90 at.% and the thickness of the deposition 130 nm. The large deposition of carbon might have been caused by the accumulation of carbon eroded at graphite divertor tiles during both

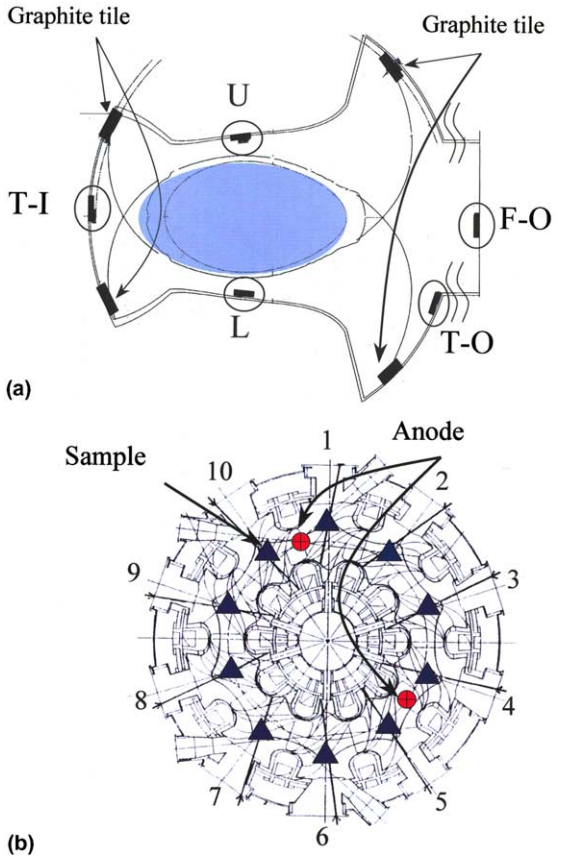

Fig. 1. (a) Poloidal locations of material probes placed at toroidal sector, #7. (b) Toroidal locations of material probes and anodes.

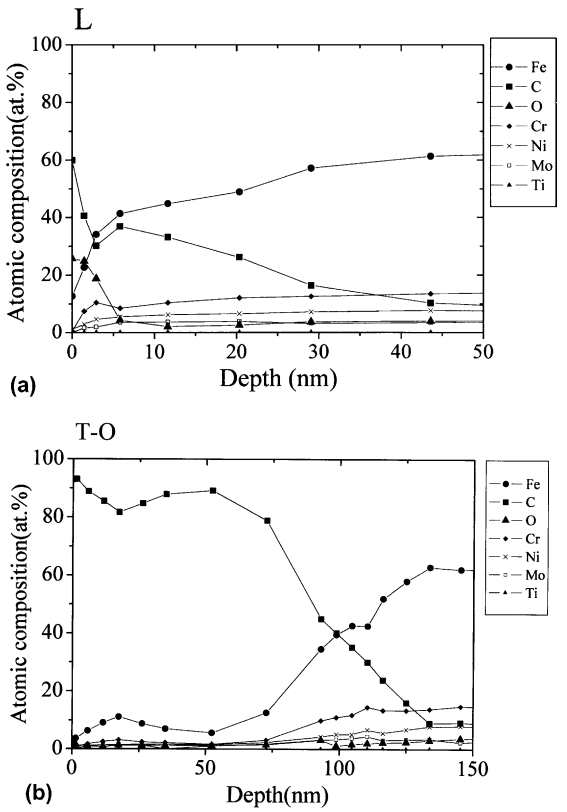

Fig. 2. Depth profiles of atomic composition for stainless steel samples located at lower first wall (a) and around outer divertor region (b).

the main discharges and glow discharges. The position of the sample L was very close to the main plasma. It was assumed that the particle flux of charge exchange neutrals to the first wall was large and resulted in large erosion. The position of the sample L was far from the graphite tiles. In contrast, the position of the sample T-O was very close to the graphite tiles and it was likely that carbon atoms sputtered on the surface of graphite tiles were easily deposited around them. In the case of the sample F-O, large carbon deposition might be due to transport of hydrocarbon, which was caused by chemical sputtering on the surface of graphite tiles [4].

In order to clarify whether the carbon deposition occurred during main discharge or glow discharge, the probe samples exposed only to main discharges or only to glow discharges were prepared. These probes were placed at the port of the toroidal sector, #7. Fig. 3 shows the depth profiles for atomic composition for the stainless steel probe exposed only to main discharges (a) and only to glow discharges (b). On the surface of the stainless steel probe exposed only to main discharges (Fig. 3(a)), the carbon deposition with thickness of 60 nm and concentration of 90 at.% was observed. On the surface of stainless steel probe exposed only to glow discharges (Fig. 3(b)), the amount of carbon deposition was small compared with that on the stainless steel probe exposed only to main discharges. It is concluded that the graphite divertor tiles were eroded mainly during main discharges and the eroded carbon was then deposited on the entire wall.

3.2. Retention of discharge gases and impurity gas

The retained amounts of helium and hydrogen in stainless steel probes placed along the poloidal direction are shown in Fig. 4. Here, the desorption amounts were obtained by time-integration of the desorption rate within the heating time of 2000 s, corresponding to the TDS's temperature of 1000 °C. The helium retention was large at the walls, T-I, L and U, and small at the wall far from the plasma, T-O and F-O. It is presumed that the helium retention took place owing to implantation of both charge exchanged helium particles during the main discharge and helium ions during the helium glow discharge. The helium flux might be large at the wall near the plasma, and then the retained amount of helium might have been large near the plasma. On the other hand, the retained amount of hydrogen was large in the probes placed far from plasma. Since the deposition of carbon was large at the region far from the plasma and the carbon largely retains the hydrogen, the retained amount of hydrogen might have become large in the probes far from plasma.

Fig. 5 shows the retained amounts of helium and hydrogen in stainless steel probes placed along the toroidal direction. In this figure, the positions of two anodes are shown. The retention of discharge gas was large near anodes. This result corresponds to the current density of the glow discharge. The retention of impurity gas such as H_2O, CO and CO_2, were also large near the anodes. It is presumed that the impurity gas emitted from wall might have been ionized in the vicinity of the anodes.

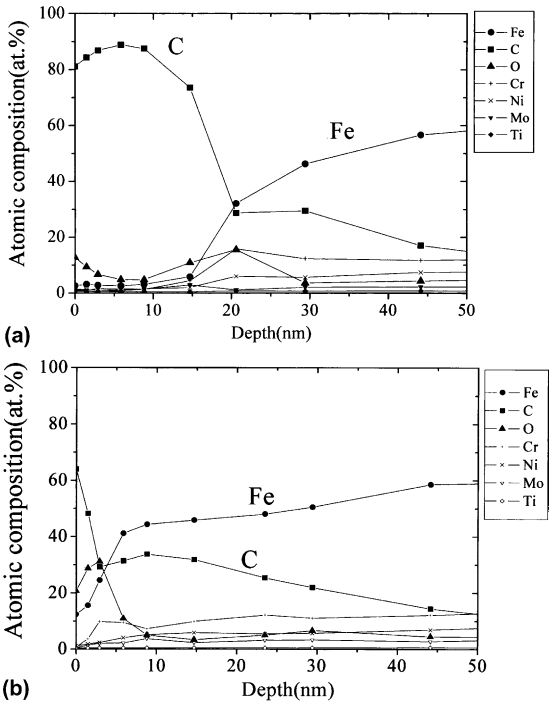

Fig. 3. Depth profiles of atomic composition for stainless steel samples exposed only to main discharges (a) and only to glow discharges (b).

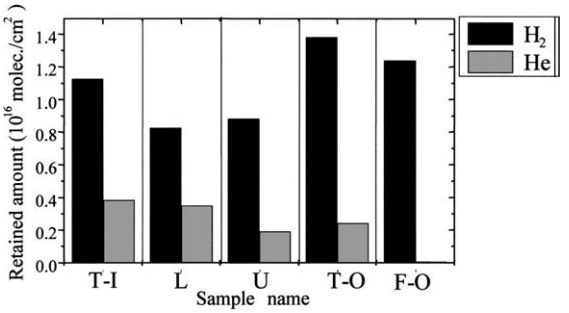

Fig. 4. Retained amounts of helium and hydrogen in stainless steel samples placed at the inner wall along the poloidal direction.

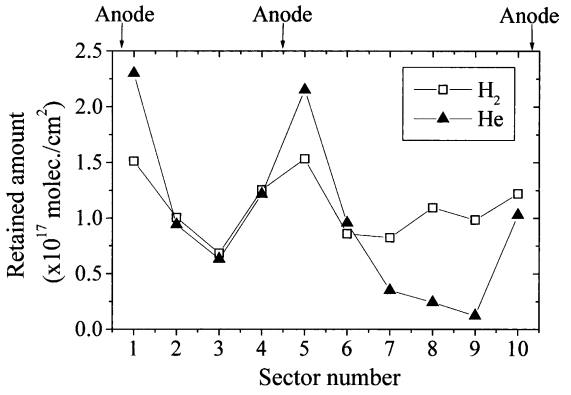

Fig. 5. Retained amounts of helium and hydrogen in stainless steel samples placed at the lower first wall along the toroidal direction.

4. Conclusions

The change of wall surface was analyzed using the material probes for the 4th experimental campaigns of LHD. Since the graphite tiles have been installed at the entire region of the divertor target, the wall surface was significantly covered by the carbon. On the surface of the probe, the carbon concentrations at the first wall and the wall far from the plasma were 60 and 90 at.%, respectively. It was also shown that the deposition of carbon was dominant during the main discharges. In the 4th campaign, the metal impurity concentration was reduced to a half of the 2nd campaign, which was conducted without graphite tiles [5]. This results was similar to the case of the 3rd campaign. However, the hydrogen gas retention increased by the deposition of carbon. In particular, the hydrogen retention was large at the walls far from the plasma.

The retained amounts of hydrogen, helium and impurity gases were large near the anodes. The difference of gas retention in the toroidal direction depended significantly on the current density in the glow discharge.

Acknowledgements

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