§34. Change of Surface Properties of First Wall in LHD Due to Installation of Close-Divertor

Yoshida, N., Watanabe, H., Kimura, Y., Tokunaga, T., Futagami, N., Fujiwara, T. (Kyushu Univ.),
Oya, Y., Okuno, K. (Shizuoka Univ.),
Hatano, Y. (Toyam Univ.),
Masuzaki, S., Tokitani, M., Ashikawa, N.

We are continuously studying on macroscopic and microscopic modifications of the plasma facing surfaces in LHD caused by interaction with plasmas for understanding their roles on plasma confinement. Here, main results obtained from the experiments carried out in the 14th and 15th cycles will be briefly reported.

(1) Surface modification by glow-discharge cleaning at start-up

In LHD long glow discharge cleaning (GDC) are always carried out at the beginning of each experimental cycle. In case of the 14th cycle, GDC with Ne gas (Ne-GDC) for 12 hours, H gas (H-GDC) for 122 hours and He gas (He-GDC) 24 hours were done successively to clean the plasma facing surfaces ahead of main plasma discharge experiments of the cycle. In the present work, several kinds of metal samples (W and SS 316L) were placed at the wall position by using the retractable material transfer system located at 4.5L port and exposed to the GDC at start-up. After finishing the series of GDC the samples were taken out from LHD and their surface properties were examined by using TEM, SEM, GD-OES and XPS. The plasma facing surfaces of the both metals were heavily modified in a similar manner, namely, The top surface of about 8~10 nm-thick is heavily deformed due to the radiation induced cavities of nano-size (1~5 nm in size), probably He bubbles, and fine dislocation loops. Nano-size crystals are also formed in the deformed layer. Though the surface is covered mainly by C originated from the divertor tiles made of isotropic graphite, O, N, elements of the inner walls (Fe, Cr, Ni) and substrate element (W) were also detected. In the area just beneath the modified layer, dense fine He bubbles widely distribute. These results indicate that complicate sputtering erosion and re-deposition processes, which occur simultaneously under the GDC, make the mixing layer mentioned above. It was reported that formation of fine bubbles occurs only under He-GDC and increases retention of H very much. Quite similar modified surface layers were also observed in the metallic samples exposed to the whole plasmas at the sputtering dominant region through the experimental cycle. These results indicate that the properties of the plasma facing surface of LHD were not the original one of stainless steel, but those with heavily modified layer at the surface from the beginning of the cycle.

(2) Change of surface properties of long-term samples

Many numbers of specimens of W and SS 316L were placed on the protection wall near 8I port and 9I port, which are close to a traditional open-divertor and a newly installed close-divertor, respectively. Positions of the specimens of the 14th cycle (2010) are illustrated in Fig.1. Characteristics of each sample were examined by TEM, SEM, GD-OES, XPS and TDS after finishing the whole plasma discharge experiments of the cycle. Effects of the close-divertor were remarkable. Namely, most examined areas in the open-divertor region (positions 8I-3, 8I-4 and 8I-5) are more or less deposition dominant, while the corresponding areas of close-divertor region (9I-3, 9I-4 and 9I-5) are erosion dominant. It is considered that large divertor plates effectively suppress the flow of sputtered C from the strike-points on the divertors to the wall nearby. However, very thick deposition of C together with H was found under the close-divertors (9I-0 position, shadow area).

In case of the 15th cycle, on the other hand, deposition dominant area expanded and thickness of the deposition increased comparison with the 14th cycle and before. The area close to the open-divertor were fully covered by thick C dominant deposition (30-460nm thick) and even in the area near the close-divertor plasma facing surfaces were covered partially by thick C dominant deposition (9I-4, 75nm). Judging from the microscopic structure observed by TEM, main source of the deposited C is the facing divertor tiles. It is considered that large reinforcement of plasma heating power carried out in this cycle increased the heat load and particle load on the divertors and resulted in the remarkable enhancement of C deposition.

As reported so far it was confirmed that modification of the surface layer drastically increased the ability of hydrogen retention. At erosion dominant area, where thin modified layer was formed as mentioned above, hydrogen can be trapped very densely (H/M≦0.05) up to 500K. At deposition dominant area, more hydrogen can be trapped up to 1000K. Such strong retention of hydrogen will make difficult to control particle balance, which is essential for steady-state operation. Reduction of C deposition originated from the divertor will become more and more serious issue with increasing heating power. Installation of W coated divertors is one of the options

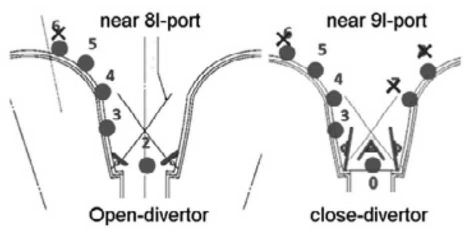

Fig. 1 Position of long-term samples in the 14th cycle