§9. Comparison of the Wall Conditioning Effects between ICH and ECH Discharge Cleaning from a Viewpoint of the Microscopic Modification of the First-wall Surface of the LHD

Tokitani, M.,
Takahashi, H., Nakano, T., Nagaoka, K., Kasahara, H., Yoshimura, Y., Masuzaki, S., Ueda, Y., Yoshida, N., Ashikawa, N., Nagasaki, K., Mutoh, T., Yamada, H., LHD Experiment Group

The high ion temperature (high-T_i) plasma is necessary for fusion reactors. The Large helical device (LHD) has an important advantage for realizing the fusion relevant high-T_i plasmas by using its high-power plasma heating facilities of neutral beam injection (NBI), ion cyclotron heating (ICH), and electron cyclotron heating (ECH) systems. For the high-T_i experiment, ICH+ECH discharge cleaning with helium gas puffing (helium plasma) is normally used between the high-T_i plasma discharge for reduction of the undesired gas recycling (mainly hydrogen) from the first-walls and divertor surface. Such a discharge cleaning technique seems to be effective for high-T_i discharges so far. However, cleaning mechanism of the ICH+ECH discharge still has not been understood yet. The elucidation of the cleaning mechanism is important for optimization of the high-T_i plasma experiment. In addition, LHD experiment group are thinking of applying a simple ECH discharge cleaning with helium gas puffing also. If the ECH discharge cleaning also makes a same effect with ICH +ECH cleaning, it would act as a useful tool for high-T_i plasma experiment. In this study, therefore, for clarify the cleaning mechanism of the wall surface by ICH+ECH discharge cleaning, material probe experiment was performed by using retractable material probe system equipped with LHD. In addition, for comparison with ICH+ECH discharge cleaning, material probe experiment with ECH discharge cleaning was also performed. For the first step of the investigation of the cleaning mechanism, this study focused on the surface cleaning effects of SUS316L first-wall panels and not included the divertor tile surface.

Stainless steel (SUS316L) specimens were mounted on the probe head. The probe head was inserted into the first wall equivalent position, and then, exposed to the ICH+ECH and ECH discharge cleaning for several discharges. For comparison between two cleanings, we tried to set a same input energy at two cases. Consequently, the total input energy of the ICH+ECH discharge cleanings and ECH cleanings were estimated to be around 327 MJ and 362 MJ, respectively. After the exposure, microscopic modification caused by helium bombardment was observed by using transmission electron microscope (TEM). In addition, retention characteristics of the helium in the SUS316L specimens was analyzed by using thermal desorption spectroscopy (TDS) analysis.

Fig. 1 shows the TEM images of the SUS316L specimens after exposed to the ICH+ECH discharge cleanings. The upper series shows the helium bubbles and lower series shows the dislocation loops. The helium bubbles with size of around 1-3 nm were densely observed in both cases. In addition, dislocation loops with size of 1-20 nm were also observed around the bubbles in both cases. The size and density of the helium bubbles and dislocation loops in these two cleaning cases were almost same. This means that the injected energy of the helium into the SUS316L matrix could be almost same. However, diffused electron diffraction pattern can be seen only in the ICH+ECH discharge cleaning case. Since the diameter of the diffraction ring does not fit the SUS316L substrate diffraction spot, deposition layer seems to be composed by the typical composition of the deposition layer formed on the LHD such as carbon dominant Fe layer. Namely, formation of the deposition layer was only differencing point of between ICH+ECH discharge cleanings and ECH cleanings. On the other hand, TDS spectra of helium from SUS316L specimens after exposed to these two cleaning cases are shown in Fig. 2. Not only the amount of the total desorption of helium but also their desorption peaks were quite similar. Judging from Fig. 1 and Fig. 2 results, the cleaning effects between ICH+ECH and ECH cleaning against the SUS316L first-wall surface are almost same. The effects of the deposition layer formed on the first-wall surface during the ICH+ECH discharge cleaning for hydrogen recycling has not clarified yet. If we would want to completely understand the effects of the ICH+ECH discharge cleanings, further fundamental experiment should be conducted. In addition, the surface conditions of the divertor tiles could also influence to the hydrogen recycling. The investigation of the cleaning effects of divertor surfaces also should be conducted in the future.

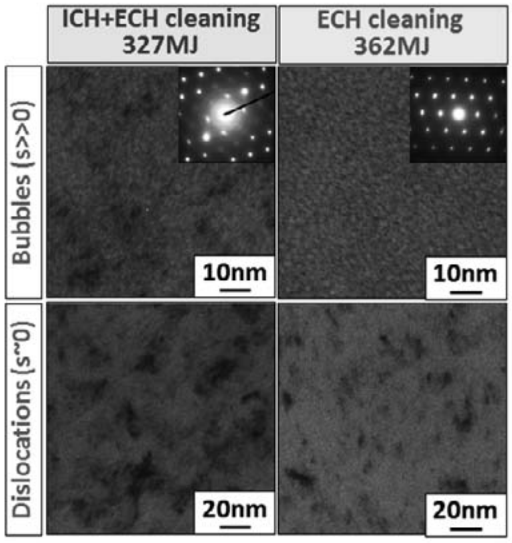

Fig. 1. TEM images of the SUS316L specimens and corresponding electron diffraction pattern after exposed to the ICH+ECH discharge cleanings with the total input power of around 327 MJ to the plasma and the ECH discharge cleanings with the total input power of around 362 MJ to the plasma.

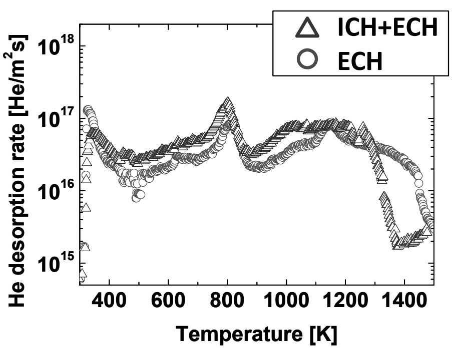

Fig. 2. TDS spectrum of helium from the SUS316L specimens after exposed to the ICH+ECH discharge cleanings and the ECH discharge cleanings.