

§4. Influence of the Surface Morphologies of the Plasma Facing Materials in LHD for Steady State Plasma Operation

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Large helical device (LHD) has a large advantage for steady state operation (SSO). One of the key issues of the establishment for SSO in LHD is the control of the plasma surface interactions (PWI). First wall panels and divertor plates of LHD are stainless steel (SUS316L) and graphite, respectively. The former is the major material in LHD, and the graphite area is only about 5% of the total plasma facing area. The temperature of the first wall is almost kept at room temperature (R.T.) during plasma discharges. Therefore, PWI phenomena of the SUS316L at near the R.T. are important for SSO in LHD. According to the previous SSO discharges, plasma collapse sometimes occurred due to the uncontrollable density increase. In such case, first wall surface might have changed from the sink to the source with increasing the plasma duration time due to the plasma particle bombardment. It is necessary to know which types of the surface condition of the first wall (SUS316L) promote the desorption of the particle. In this study, material irradiation experiments were conducted to the SSO discharges with He and hydrogen gas puffing. After the exposure, microscopic modification and retained He particles were examined by using transmission electron microscope (TEM) and thermal desorption spectroscopy (TDS).

Pre-thinned discs of 3mm diameter and plates of 0.1mm thickness of vacuum annealed SUS316L were prepared. They were transferred to the equivalent position to the first wall surface through the 4.5 lower port by mounting on the head of the retractable material probe system attached to the LHD and then exposed to the ICH and ECH heated SSO discharges with He or hydrogen gas puffing. The exposure conditions are summarized in Table 1. We separated the experiment days as an early and a latter phase. The conditions 1A and 1B were conducted in early phase, and the others were conducted in latter phase.

Fig. 1 shows the cross-sectional TEM images of the SUS316L specimens after exposed to 1A and 2B conditions. In the case of the 1A, fine He bubbles with size of 1-5 nm were densely formed in the sub-surface region (~20 nm). The projection range of the 2keV-He calculated by TRIM-code is shown together with this image. It is clear that depth distribution of the bubbles are almost corresponds to the calculation range. This means that majority of the injected energy of the He particles was on the order of several keV. This value almost corresponds to the ion temperature of the ICH&ECH heated He discharges. In the case of the 2B, He bubbles are observed in the almost same depth of the 1A case. However, deposition layer mainly composed with the thickness of about 5-10nm by carbon was formed on the surface. Such deposition layer was also formed in the 1B and

2A case. By compare with 1A and 2B case, deposition rate of the carbon dominant layer seems to be increased in the latter phase of the plasma experiment.

Fig. 2 shows the TDS spectra of He from 1A and 2B case. We can distinguish three types of trapping peak (mechanism). First type is the He bubbles, desorption peaks appeared at 1000-1400 K in both 1A and 1B case which indicated as hatched region of (1) in the figure. Since this trapping site has the strongest trapping energy of He in metals, these He are difficult to desorb up to about 1000 K, and would not influence the density control of the plasma by sudden increasing of the wall temperature. Second one is the weak trap of the hatched region of (2) at 300-620 K in Fig. 2-(1A). The desorbed He in this region is from the weak trapping site from a strong distortion field such as dislocation loops [1]. Third one is hatched region of (3). This trap site is also weak trapping energy but the mechanism is different with (2). Most of the desorbed He in (3) is trapped by the carbon dominant deposition layer. Desorption of He from weak trapping site such as (2) and (3) would cause the effect to the density control because they suddenly released even at around 400 K. Since thermal conductivity of the deposition layer is lower than bulk SUS316L, temperature of the deposition layer would be increased with ease comparing with bulk SUS316L. Therefore, such a rapid desorption would be more noticeable at case (3).

[1] M. Tokitani et al., J. Nucl. Mater. 329–333 (2004) 761

Condition	1A	1B	2A	2B
Heating and total time	ICH&ECH (~1MW) (He) 948s + ECH (H) 175s	ECH(0.4MW) (H) 174s	ECH (0.24MW) (He) 1000s	ICH&ECH(1MW) (He)1000s
Exp. day	Early phase (2012 10/26, 29)		Latter phase (2012 12/5, 6)	

Table 1. Exposure condition of the SUS316L specimens.

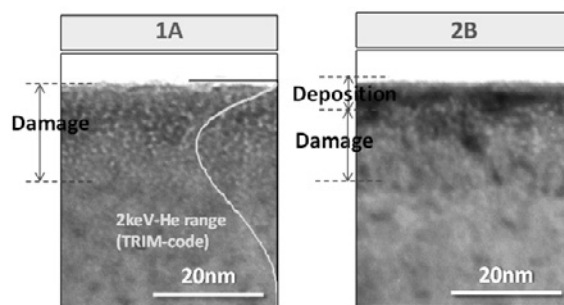


Fig. 1. Cross-sectional TEM image of the SUS316L specimens after exposed to 1A and 2B conditions.

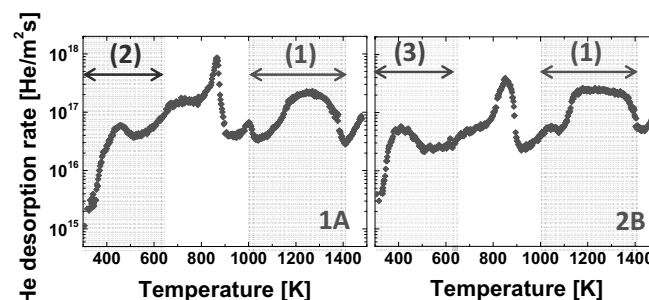


Fig. 2. TDS spectra of He from SUS316L at 1A and 2B cases