§66. Damage Accumulation on the First-wall Surface in LHD Exposed to Neutral Helium Particles

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The first wall materials of fusion reactors suffer heavy bombardment of helium particles generated by D-T fusion reaction. Majority of such incidence helium particles are energetic neutrals (CX-neutrals) created by charge-exchange collisions [1]. Understanding of the effects of CX-helium atoms to the first wall is important for not only the elucidation of materials degradation but also the plasma operations. In the present study, microscopic damage and helium depth profile in metals bombarded by CX-helium atoms during LHD helium discharges was studied, and then, incidence flux and energy of CX-helium were evaluated. Furthermore, to investigate the effect of optical reflectivity due to CX-helium exposure for Mo, change of optical reflectivity was measured by means of spectrophotometer, because Mo is one of the potential candidate of first mirror for plasma diagnosis in future fusion devices [2].

Specimens of Mo and SUS mounted on the probe head were placed at the near first wall position by using the retractable material-probe system which attached to LHD, and then, exposed to the ICRF heated helium plasmas. This probe system makes possible to select desirable plasma discharges and irradiation position by using shutter and vertical movement mechanism. Table I shows total discharge time at each irradiation position which is identified by the distance measured from the first wall position. For convenience these positions are denoted as (A), (B) and (C). (B) and (C) are the positions in 4.5L port. After the exposure, microscopic damage of the specimens was studied by means of transmission electron microscopy (TEM). Optical reflectivity of Mo before and after the exposure was measured with a spectrophotometer for the wave length between 190 and 2500nm.

Fig. 1 shows TEM images of Mo specimens exposed to the ICRF helium discharges for the case of (A), (C) and (A)+(B)+(C). (A)+(B)+(C) means the specimen exposed at all positions. Although total irradiation time was only 349s~1138s, considerably large amounts of helium bubbles of about 1 to 2nm and dislocation loops of about ~20nm were formed in all cases. Evolution of the microscopic damage was already saturated at the case of both (A) and (B). This means that the damage is caused by CX-helium which can penetrate even in the port, and their energy and flux are sufficiently higher to create these defects. For example, minimum energy (E_{min}) for creating the knock-on damage to Mo is 0.23keV. The size and density of defects between (A) and (B) were very similar. It is indicates that the flux of CX-helium does not decrease much even in the port. Such serious defects were observed also in SUS specimen.

It was tried to estimate the flux and energy of CX-helium to the first walls by comparing with systematic helium ion irradiation experiments [3,4]. The estimated flux and incident energy from size and density of the defects is the order of $\sim 10^{19}$He/m^{2}s, and about 1~2keV, respectively.

Fig. 2 shows the optical reflectivity of Mo exposed at (A)+(B)+(C). Reflectivity of virgin sample was also plotted. It is clear that reduction of reflectivity has already occurred at the exposure time of only 1138s. Referring to our previous study [5], it is consider that reduction of optical reflectivity is due to the multiple scattering of light by the dense helium bubbles in the sub-surface region. This result is important for the first mirror plasma diagnostic system.

Generation of such high flux and high energy CX-helium is serious problem for not only the deterioration of the first wall materials but also plasma diagnosis by using metallic mirrors. In addition, phenomena in plasma confinement devices such as synergistic effects of helium bombardment and re-deposition will be investigated.

	Distance from first wall position	Total shot	Total discharge time
(A)	0cm	13	408s
(B)	-5cm	81	349s
(C)	-25cm	86	352s
(A)+(B)+(C)		185	1138s

Table I. total discharge time at each irradiation distance from the first wall position. (Direction of -25cm is farthest from plasma)

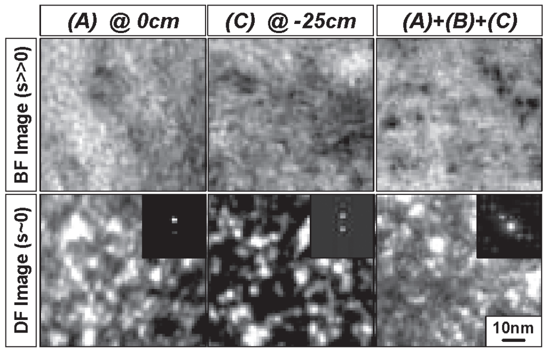

Fig. 1. TEM images of Mo after exposed to ICRF helium discharges, BF images at large deviation parameter condition (upper series). White dot contrast in DF images shows dislocation loops (lower series)

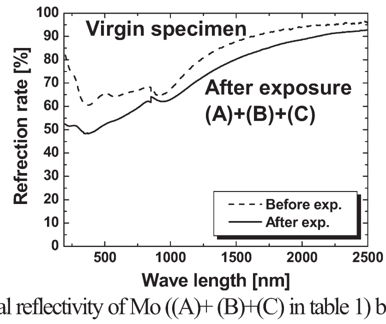

Fig. 2. Optical reflectivity of Mo ((A)+ (B)+(C) in table 1) before and after exposure to helium discharges.

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