§35. Estimation of CX Incident Parameter with Material Probes

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Material probe experiments have been employed as efficient methods to investigate the PSI phenomena in many plasma confinement devices. In LHD and TRIAM-1M, material probe experiments have been performed from the viewpoint of microscopic damages in plasma-facing materials (PFMs).[1,2] It was elucidated that charge exchange (CX) neutrals have large impacts not only on surface modifications of PFMs but also on plasma density control. However, most previous research has dealt with superimposed effects due to plasma exposures in various conditions, and has not examined phenomena caused by a specific plasma condition. In this study, effects under certain plasma conditions are clarified by a controlled material probe experiment, and incident parameters of CX-neutrals such as energy distribution and flux are quantitatively inferred for each plasma condition. In addition, the availability of this method as a CX- neutrals monitor is discussed.

To examine microscopic surface modifications due to CX-neutrals bombardment under specific plasma conditions, controlled material probe experiments were performed with pre-thinned samples. The samples were exposed to identical plasmas by using a retractable material probe system and a rotary shutter equipped to a material probe head. These devices enable to avoid exposing samples to discarded plasmas. Table 1 (left) summarizes the plasma conditions used in the present study.

Fig.1 displays TEM images of the probe samples exposed to (a) low and (b) high density hydrogen plasmas. It is clearly seen that radiation-induced dislocation loops, shown in white contrast, are formed in all the samples. The damage density in the samples exposed to low density plasmas is found to be much higher than that in the samples exposed to high density plasmas. Comparing the damage density between the samples exposed to LHD plasmas and those irradiated with H^+ ions, the fluxes can be roughly estimated as shown in table 1 (right). These energies approximately agree with estimates from a modeling analysis of particle transport. Fig.2 shows the energy dependence of the generation rate of CX-neutrals calculated with the 3D edge neutral transport code EIRENE [3] using T_e and n_e profiles obtained in experiments. This indicates that the high energy component, which causes the knock-on damage, is much higher in low density plasma than in high density plasma.

The observation of the samples exposed to helium plasma revealed the formation of high density helium bubbles even at high sample temperature where no defects form in case of hydrogen plasma. This means that helium plays a dominant role on the defects formation of PFMs

While there is an accuracy limitation, it is important to mention here that the material probe has availability to evaluate the CX-neutrals load to first walls quantitatively just using small samples.

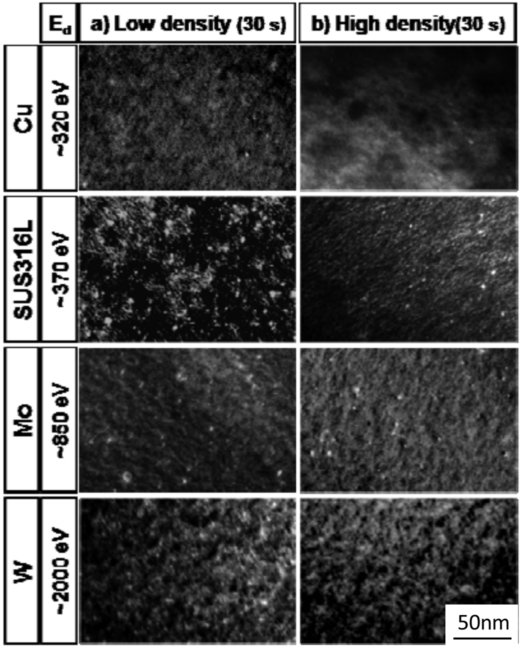

Fig. 1 Microstructure of material probes exposed to hydrogen plasmas for about 30 s in LHD.

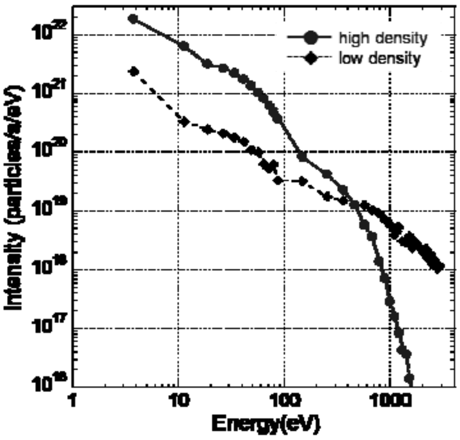

Fig. 2 Energy dependence of the generation rate of CX-neutrals calculated with EIRENE.

1) M. Miyamoto et al., J. Nucl. Mater. 337-339 (2005) 436
2) M. Tokitani et al., J. Nucl. Mater., 367-370 (2007) 1487
3) D. Reiter et al., Fusion Sci. Technol. 47 (2005) 172-186

Table 1 Plasma conditions used in this study (left) and the estimated CX flux for each specific plasma (right).

Plasma	Sample temp.	duration (s)	T_i (keV)	n_e (m^{-3})	Estimated CX flux ($/m^2s$)
H (low density)	R.T.	30 (6 shots)	1~2	$\sim1\times10^{19}$	6.7×10^{19} (>370eV), 1.5×10^{19} (>850eV)
H (high density)	R.T.	30 (6 shots)	1~2	$\sim6\times10^{19}$	2.6×10^{19} (>370eV), 0.9×10^{19} (>850eV)
He (RT samples)	R.T.	87 (64 shots)	0.5~2	$1\sim10\times10^{19}$	$\sim0.5\times10^{18}$
He (HT samples)	773 K	40 (13 shots)	0.5~2	$1\sim10\times10^{19}$	