§98. Evaluation of Chemical Composition and Retained H and He at Plasma Facing Surfaces of LHD and QUEST

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In case of LHD and QUEST performing long-pule operations frequently, properties of the plasma facing surfaces such as chemical composition and microstructure, change due to strong plasma wall interaction (PWI). It is likely that these phenomena affect recycling of the fueling particles and also integrity of the plasma facing materials. For steady-state operations, which will require active control of fueling particle recycling, information of the surface properties is essentially important.

Many probe-samples must be put on the wall from place to place to monitor the change of the surface properties globally, because PWI is not uniform in the torus. In the preset work GD-OES has been used preferentially for chemical analysis, because the measuring time is quite short, less than 10 minutes per sample. In this fiscal year more than 100 samples form Cycle-17, Cycle-18 of LHD and 2013AW, 2014SS from QUEST were analyzed. Due to limited space, only the analysis of retained He in SUS316L exposed to Cycle-17 plasmas will be reported here.

According to the cross-sectional TEM observation, the surface of a sample exposed to plasmas at an erosion dominant area (C17-9I-5) is covered slightly (about 2nm-thick) with re-deposited impurity atoms as C, Fe, Cr and O. A large number of He bubbles have been formed in SUS316L substrate. Well grown He bubbles of about 5-15nm in diameter exist especially in the narrow sub-surface region of about 15nm-thick, while smaller ones distribute up to about 50nm in depth. Retained He was measured by the GD-OES equipment at University of Toyama using Ne as working plasma. Depth distributions of He retained in the SUS316L samples at the erosion dominant area (C17-9I-3, C17-9I-5) are plotted in Fig. 1 together with those of SUS316L irradiated with 2keV-He^+ at room temperature up to $3x10^{20}He^+/m^2$ and of virgin one. Rather high background even in the virgin sample must arise from Cr which emits light with wave length close to that of He. The sputtering rate under Ne plasma bombardment was estimated at about 25 nm/s from the depth of the sputtered crater. In case of 2keV-He^+ irradiation, the peak of He distribution corresponds well with theoretically estimated projected range at 8nm, while He spread beyond the theoretical depth distribution ($\leq$ 30nm). On the other hand, He in the LHD samples have a sharp peak at around 2-5nm in depth, while some part of He distribute up to 50-60 nm in depth. Depth distribution of He and He bubbles agree very well. The highly localized distribution of He must reflect energy distribution of charge exchanged He bombarding the plasma facing surface. Theoretically estimated apa/s and dpa/s at the surface of SUS316 localize in the area less than 3nm and 15nm, respectively.

By assuming that most of the He atoms injected by the 2keV-He^+ irradiation are retained in the subsurface region less than 50nm, ratio of He/metallic-atom at the peak is estimated to be 0.25. Based on this result, peak value of the ratio in the LHD samples is 0.2~0.27. One should note that heavy damage due to PWI is mainly caused by He plasma discharges. Contribution of H plasma discharges is limited although they are majority of the experiment.

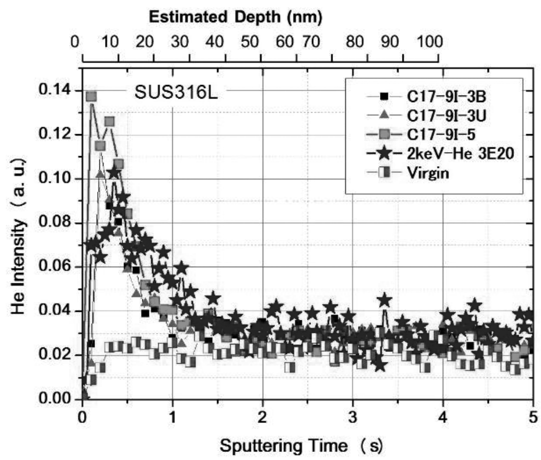

Fig. 1 Depth distribution of He in various SUS316L samples measured by GD-OES. LHD samples (C17-9I-3, C17-9I-5), He ion irradiated one and virgin one.