§31. Study on Microscopic Damage of Plasma Facing Materials in LHD

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The understanding of PSI (Plasma Surface Interaction) is one of the most critical issues for further nuclear fusion reactor. Authors have reported that charge exchange (CX) neutrals has large impacts on not only the surface modifications of PFM (Plasma Facing Material) but also plasma density controlling as the results of material probe experiments in plasma confinement devices, TRIAM-1M and LHD [1,2]. On the other hand, it is well known that the temperature has considerably impact on formation processes of radiation damages. In the present work, therefore, microscopic damage in metals exposed to plasma in LHD at high temperature was examined.

To examine the surface modification of high temperature walls, a materials probe experiment was carried out. Pre-thinned vacuum-annealed disks of 3 mmϕ made of Cu, Mo, W and SUS316L were used as specimens. These specimens were mounted on the material probe system equipped with a heatable sample holder. Fig.1 shows the newly-created sample holder which allow heating from R.T. to 873K with an error of less than 10K. The specimens were placed at the similar position of the first wall surface through the 4.5 low port, and exposed to main helium plasma for about 40 s (Shot No. 81344~81356). The thermal regulator held the specimens almost constant temperature of 773K during the discharges. After exposing the discharges, the microstructure of specimens was observed by means of transmission electron microscopy (TEM). In addition, thermal desorption experiments for quantifications of retained helium and irradiation experiments for comparison of damage structures were also carried out.

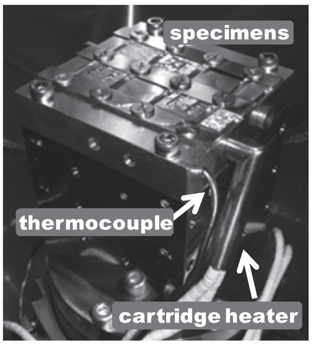

Fig.1 The heatable sample holder

In the specimens exposed to helium plasma at 773 K, characteristic damages were formed. Fig. 2 shows the microstructure of the specimens. The radiation-induced dislocation loops with black contrast besides helium bubbles with white contrast were observed in these specimens. Exceptionally, no dislocation loop was observed in Cu, which was attributed to depression effect of the temperature on the damage nucleation. In general, radiation induced secondary defects formation is suppressed by keeping materials at high temperature, which is seems to be benefit in the use of materials at high temperature. However, it should be noted that existence of helium causes stable defects formation such as helium bubbles. Furthermore, it was reported that the helium-vacancy complex act as stable nucleation site for dislocation loops[3]. The high-density dislocation loops shown in Fig. 2 were also seemed to be due to helium-vacancy complexes.

In the estimation of incident helium flux, the value of 5×10^{17} H/m^2s was roughly estimated from the thermal desorption and in-situ irradiation experiments. The comparison of microstructure between the LHD sample and irradiation experiment in laboratory also indicated similar incident flux consisted with the result of TDS.

Damages related to He irradiation are so serious and very stable even in high temperature, earnest studies for reduction of these damage formation are required.

1) M. Miyamoto et al., J. Nucl. Mater., 329-333 (2004) 742
2) M. Miyamoto et al., J.Nucl.Mater., 337-339 (2005) 436
3) K. Arakawa et al., J. Appl. Phys., 89(2001)4752

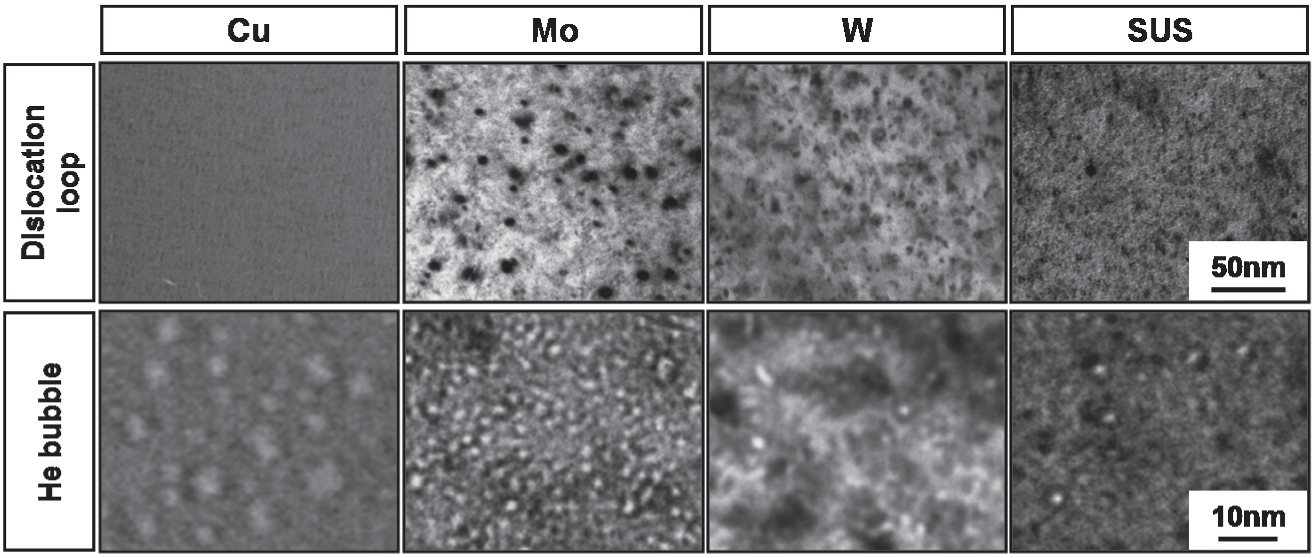

Fig. 1. Microstructure of material probes exposed to the helium plasma for 40 s.