§71. Evaluation of Modification and Damage of Plasma Facing Surface of LHD

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Interaction of mixed plasma of hydrogen isotopes and helium with the wall surface is one of a key issue for burning plasma devices. On the other hand, it is expect that helium plasma induces damage at the wall surface in the devices utilizing helium glow discharge cleaning such as LHD. In the present work, radiation effects for the wall materials in LHD by helium/hydrogen plasma have been studied by using electron microscopy, atomic force microscopy, scanning electron microscopy, thermal desorption spectroscopy and so on.

1. Investigation of atomistic mechanism of damage by helium glow discharge cleaning and proposal for the improvement of glow discharge cleaning method

Glow discharge cleanings with helium, hydrogen or neon have been carried out in LHD. In order to understand the phenomena induced by the discharges, tungsten and several other kinds of metals were exposed to the discharges by using the retractable material prove system attached to 4.5-L port. It was clarified that the damage and erosion of the surface layer depend strongly on the type of gas as followings. (1) Helium discharges induce very strong radiation effects on the surface layer. As shown in Fig.1, lattice defects such as helium bubbles, dislocation loops and nano-size cracks were densely formed in the surface layer about 45nm-thick, which was much deeper than the projected range of helium plasma (about 250eV). The implanted helium were trapped in the defective layer, and some part of them release slowly even at room temperature. In actual, the helium desorption has often disturbed hydrogen plasma experiments. This result indicates that helium glow discharge is not ideal for the discharge cleaning due to the undesirable strong trapping of the gas in the damaged layer. (2) In the case of hydrogen discharge cleaning, sputtering efficiency is low but no remarkable damage were accumulated. (3) In the case of neon discharge cleaning, shorting of the discharge cleaning time can be expected because of its very high sputtering efficiency, about 10 times higher than that of helium. Moreover, the fact that defects were scarcely observed indicates that trapped gas must be few.

Based on the experimental results (1)-(3), a two-step discharge cleaning, at first neon discharge cleaning for sputtering of contaminated surface and then hydrogen discharge cleaning for desorption of neon adsorbed and absorbed on the surface, was suggested. In actual, this method was applied in the 7th cycle and the time of the glow discharge cleaning was drastically shortened. This result will be reported in IAEA-20.

2. Damage of metals by divertor plasma

In the case of the exposure to the divertor plasma of hydrogen or helium, the trace of melting was observed along the foot print of the divertor-leg, though the exposure time of each discharge is short (about 1s). Beside the trace of melting, dense dimples by blistering (about 100-200nm in diameter) and bubbles (about 1-20nm in diameter) were widely formed at the surface and inside the sub-surface part, respectively even by single discharge for 1 sec. Average erosion by the blistering was estimated to be about 6.6nm/discharge, which is about one-fourth of the sputtering erosion of graphite. It is worth to note that similar blister erosion and bubbles formation also occurred unexpectedly for the hydrogen discharges (see Fig.2). Sudden change of temperature due to the pulse heating must be playing important role for the bubbling and blistering. Present results indicate that blistering must be taken into account for the estimation of erosion of tungsten as diverter armor plate.

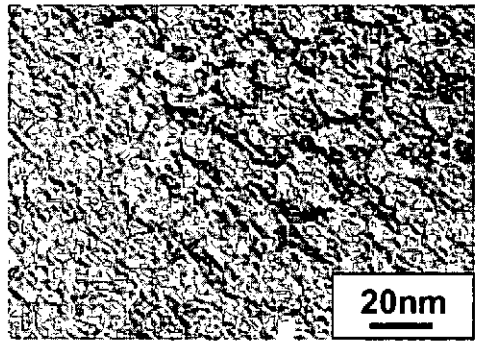

Fig. 1 TEM image of tungsten exposed to helium discharge cleaning

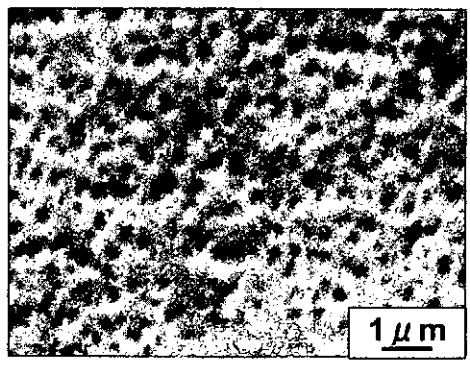

Fig. 2 SEM image of tungsten surface exposed to divertor plasma of hydrogen discharge