§75. Study on Erosion Mechanism of Materials by High Flux Divertor Leg Plasma

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i) Background and Objectives

It has been understood that hydrogen atoms injected in metals are not trapped deeply and thus blisters caused by hydrogen bubbles are scarcely formed. However, it was found in the preliminary experiment performed last year that very dense fine cavities and small blisters were formed in W specimens exposed to hydrogen divertor plasma of LHD. This unexpected result indicates that erosion by blistering and resulting plasma contamination is a new concern of the W divertor. This year, therefore, irradiation experiments with divertor plasma have been carried out to understand the mechanism of blistering under the exposure to high flux hydrogen plasma.

ii) Experimental Procedures

A W specimen (35x8x1mm) fixed on the probe head of the material transfer system equipped to the 4.5L port of LHD was moved to the divertor-leg position and was exposed to a long pulse hydrogen plasma (shot No.52730) for 30 seconds. Retention of hydrogen and deposition of impurities were measured by elastic recoil detection (ERD) and Rutherford backscattering spectroscopy (RBS), respectively.

iii) Results and Discussion

Very clear foot-print (local melting) due to high flux heat load at the divertor-leg was formed on the W specimens (See Fig.1). In addition, the probe head made of SS316L was also melted along the foot print and its droplets deposited on the W specimen nearby. Thickness of the deposit (mainly Fe) measured along line A in Fig.1 is plotted in Fig.2. In the areas beside the foot-print (10-30mm and 35-45mm), deposited Fe and substrate (W) are alloyed. It is clear that the surface temperature of this area exceeds 1500˚C significantly. Beyond the alloyed areas (<10mm, >45mm), thickness of the deposit decreases drastically. Hydrogen retention in the W specimen is also plotted in Fig.2. It increases with increasing distance from the foot-print and the areal density of hydrogen exceeds $3x10^{20}H/m^2$ at 70mm. The flux of hydrogen particles is highest at the foot-print (about $1x10^{22}H/m^2s$) but at the same time temperature increase is highest there. Difference of temperature change during the plasma discharge must be the main reason why the hydrogen retention is lower at and near the foot-print but higher at the periphery where the heat flux is lower.

Fig.3 shows an atomic force microscopic (AFM) image showing highly magnified surface morphology at 60mm, where the hydrogen retention is about $2x10^{20}H/m^2$ and almost no impurity deposition. It is clear that a large number of fine blisters (200nm in diameter, 20nm in height) are formed homogeneously and many of them have been exfoliated. High retention of hydrogen indicates that the cavities are not voids but highly pressurized hydrogen bubbles which result in blistering. The energy of hydrogen particles is only about 100eV, which is much lower than the threshold energy for the displacement damage in W. Details of the mechanism of bubble formation under such low energy hydrogen irradiation is still an open question.

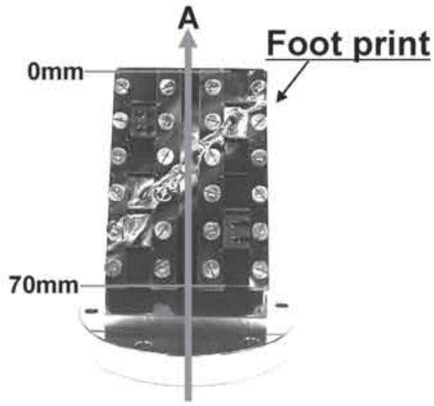

Fig.1 Probe head after exposure to the plasma

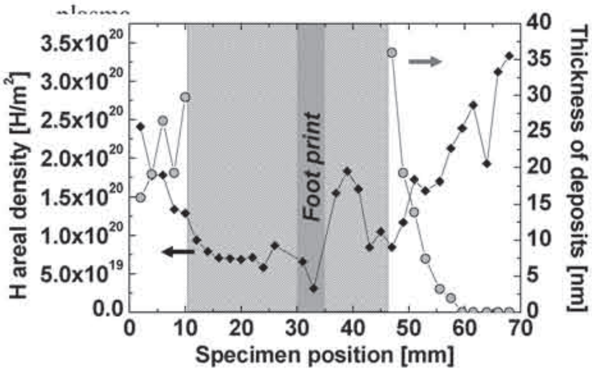

Fig.2 Hydrogen retention and thickness of deposits measured along line A in Fig.1.

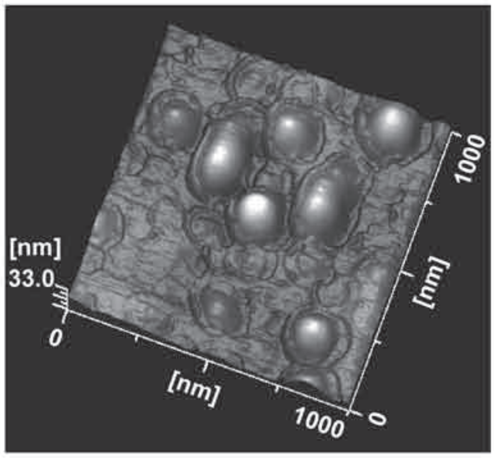

Fig.3 AFM image at around 60mm.