§48. Study on Physical and Chemical Properties of the Plasma Facing Surfaces in the Spherical Tokamak QUEST

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In order to understand physical and chemical properties of the plasma facing surfaces in QUEST due to PWI, well characterized metallic specimens (W, Mo and 316L SS) were prepared for analyses with TEM, TDS, XPS and GD-OES. In each experimental campaign, these probe specimens were exposed to plasmas through the campaign by setting on the inner wall (upper part, equator part, lower part) and lower divertor plate. In the 2011 spring/summer campaign (2011S/S), probe specimens were also set on 12 points at the lower part of the inner wall to know toroidal-dependence of PWI.

Since starting operation in 2008, QUEST has been troubled by unexpected thick deposition of carbon on the plasma facing surfaces in spite of an "all-metal machine". Fairly large area of the inner wall and some probe-specimens were remarkably colored (dark brown). In 2011S/S-campaign, however, all of the probe-specimens kept original metallic luster. Fig.1 is the cross-sectional microstructure of Mo placed at the equator part of wall. As can be expected from the metallic color, no thick carbon deposition existed but the top surface of only about 5nm-thick was heavily modified. The TEM image indicates that the modified layer is aggregate of nano-crystals and amorphous. According to the chemical analysis with XPS and GD-OES, the layer is a mixture of C, Fe, Cr, O, Mo and etc. TEM images in Fig.2 show microstructure formed in pre-thinned Mo at the equator part in campaigns 2010S/S, 2010A/W and 2011S/S. Similar damage was also observed in 316L SS and W. It is remarkable that density of dislocation loops (white dot images) formed by irradiation with energetic particles from plasma, probably change exchanged neutral hydrogen, increased drastically in 2011S/S. These experimental results indicate that not only C impurities decreased drastically but also density and energy of plasma were improved considerably in 2011S/S-campaign. Formation of radiation-induced dislocation loops in W indicates that some part of H particles bombarding the surface is higher than 2keV.

In order to evaluate the ability of hydrogen retention, the plasma exposed W specimens were bombarded by 2keV-D_2^+ to $1x10^{21}D_2^+/m^2$ at room temperature and thermal desorption od D was measured successively. Fig.3 shows TDS spectrums of W placed at equator part in 2010A/W and 2011S/S. For comparison, that of W unexposed to QUEST plasma is also plotted. All of the W specimens are recrystallized one to make clear the effects of plasma-exposure. It is worth to note that implanted D desorb thermally up to 500K and formation of thin mixed surface layer and radiation induced damage does not change much D retention, only twice. In case of LHD thermal retention of D is about 100 times higher than QUEST.

Present work indicates that QUEST has become an "all-metal machine" finally. Conditions to start a large-scale study on PWI in an all metal machine aiming steady-state operation have been satisfied.

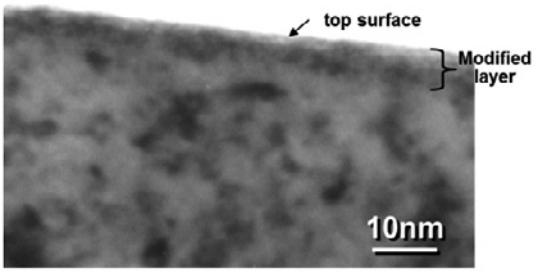

Fig.1 Cross-sectional TEM images of Mo exposed to 2011S/S plasmas at equator part of the inner wall.

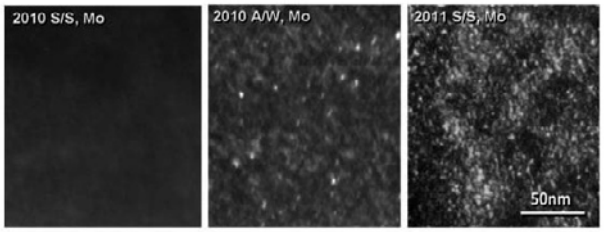

Fig.2 Formation of dislocation loops in Mo placed at equator part in the campaigns of 2010S/S, 2010A/W and 2011S/S.

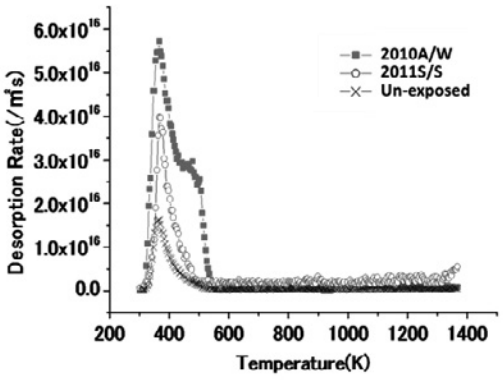

Fig.3 TDS spectrum of implanted deuterium from W exposed to plasmas in 2010A/W and 2011S/S.