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

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QUEST in Kyushu University is a medium-sized spherical tokamak aiming steady-state operation. In the experimental campaigns in 2012, the achieved pulse duration was 300s. The most possible mechanism limiting the duration of the plasma discharges would be loss of particle balance. In the present work, therefore, properties of the plasma facing surface of QUEST after the campaigns in 2012 and behavior of hydrogen isotope in the plasma exposed materials were examined to understand the mechanism of hydrogen retention and its recycling processes under long pulse operation in QUEST.

A number of probe coupons (316LSS, W, Mo) placed at the representative points on the plasma facing wall were exposed to plasmas in 2012AW (autumn/winter) campaign. Then their surface were examined by using TEM, GD-OES, XPS, TDS and etc.. Plasma facing surfaces of in-vessel components were also examined.

In the experimental campaigns in 2012 (2012SS (spring/summer) and 2012AW), long pulse discharges were carried out extensively. Due to strong plasma wall interaction, entire plasma facing surfaces were colored more or less by the deposition of impurities. As shown in the TEM micrographs of Fig. 1, impurity layers deposited on the coupons are 6~21 nm-thick and were aggregation of nan-crystals and amorphous. Thicker ones had porous layer structure.

The deposited layers were mainly composed of C (31at %), O (19 at %), Fe/Cr/Ni (33 at %) and W (16 at %). In order to understand the behavior of hydrogen in the plasma-exposed samples, deuterium ions (D_2^+) at 1 keV were injected in addition up to $1x10^{22}$ D_2^+/m^2 at room temperature, and then measured TDS of D_2, DH, H_2 and others. In case of a sample covered with a deposited layer of about 20nm-thick, D and H desorbed in the wide temperature range up to about 800K as shown in Fig.2. Though total retention of D increases linearly with increasing fluence of D, peculiar desorption of D_2 occurred at the temperature range between 350K and 400K, which correspond to the temperature of the wall under the plasma discharge experiment. Namely, in case of additional injection of $1x10^{21}D_2^+/m^2$, desorption of D is suppressed well ($1.8x10^{16}D_2/m^2s$) but it increases drastically at higher fluence ($1.4x10^{18}D_2/m^2s$ for $1x10^{22}D_2^+/m^2$).

After the detailed analysis of the TDS data, we came to conclusion as followings. (1) Though the total retention of D in the C/metal deposition is not small, most of them desorbed actively above 400K. It means that desorption from the deposition do not play major role in the out flux of H under the long pulse operation. (2) The large description at 350-500K at high fluence are from the 316LSS substrate, where D diffused from the deposition and/or directly injected have gradually accumulated under the long injection. (3) Thermal desorption of the injected D depend on the thickness of the deposition. In the area with thinner deposition absorption and desorption of the wall is very large under the plasma discharge around 373K. This will make difficult to control particle balance.

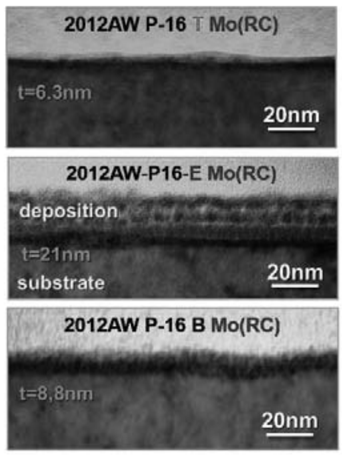

Fig. 1 Cross-sectional TEM micrographs showing impurity deposition on Mo coupons place at top, equator and bottom wall.

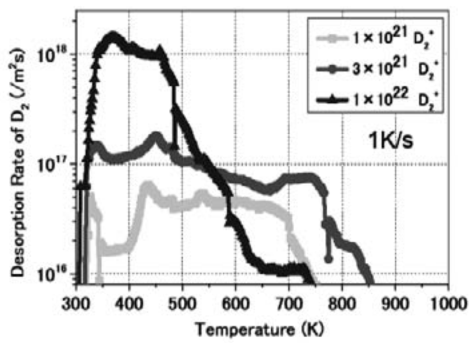

Fig.2 Thermal desorption of injected D from the 316LSS coupons covered with 21nm-thick deposition. Corresponds to 2012AW-P16-E