Measurement of D retention and poloidal/toroidal deposition pattern in tungsten blocks at outer strike point of KSTAR divertor

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ITER will have beryllium (Be) main wall and full tungsten divertor meaning that the impurity which will be deposited on remote area/tile gaps, will be Be. Since KSTAR has full carbon first wall, one can study low Z impurity migration as well as fuel retention to the surface of plasma facing components (PFCs) by putting blocks made of tungsten at the divertor. To investigate the deuterium retention and co-deposition pattern on the surface of PFCs, bulk tungsten samples were exposed to deuterium plasma discharge of KSTAR. Two sets of three tungsten samples were utilized and installed at the central divertor region. Samples in set 1 were poloidally aligned and those in set 2 were toroidally aligned, in order to distinguish the effect of the magnetic field line. Total exposure time was 28.4 s and 17.1 s, respectively. Set 1 was exposed to on H-mode of $I_p = 600$ kA, $B_t = 2.0$ T, $n_e \sim 2.6 \times 10^{19}$ m$^{-3}$, and $T_e \sim 4.5$ keV. Set 2 was exposed to on ITB discharge of $I_p = 600$ kA, $B_t = 2.5$ T, $n_e \sim 2.4 \times 10^{19}$ m$^{-3}$, and $T_e > 5.0$ keV. Layer of a-C:H (amorphous hydrogenated carbon) film was deposited on surface of all samples, depending on the particle flux in given position. The film properties were analyzed by ellipsomter and Raman spectroscopy. Total deuterium (D) retention amount was measured by thermal desorption spectroscopy (TDS). The thickness of a-C:H films was in a range of 100 nm $\sim 650$ nm in the sample 1 and 25 nm $\sim 145$ nm in the set 2, respectively with growth rate of 3.5 $\sim 22.8$ nm/s and 1.4 $\sim 8.4$ nm/s. The value of reflective index ranged between 1.6 and 2.0 meaning the variation from soft to hard a-C:H. Other specimens was in a range of 1.5 to 1.8 indicating soft a-C:H. The peak height ratio ($I_D/I_G$) analyzed by Raman spectroscopy was smaller than 0.4. The amount of retained D inside the bulk W specimens was in a range from $5.07 \times 10^{19}$ D/m$^2$ to $1.76 \times 10^{20}$ D/m$^2$. The H/(C+H) ratio in a-C:H film was $\sim 0.3$. The amount of D retained in the layer is lower than typical a-C:H thin films deposited in a controlled way in a small vacuum device. Since temperature could exceed 650 K which leads to thermal desorption of D [1] of the block surface during exposing to KSTAR there were spots where sp$^3$ bonding structures have been changed to sp$^2$. Compare with the “hot wall” operation performed in 2017 [2] which shows the D retention of $1.14 \times 10^{20}$ D/m$^2$ (NRA) at outer mid-plane, numbers are in the similar order of magnitude.

\[1\] A. von Keudell et al 1999 Nucl. Fusion 39 1451
\[2\] S. H. Son et al, PSI-23, Princeton Univ., USA, 2018