3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Simulation of carbon deposition inside gaps of castellated tungsten blocks of different shapes

Qian Xu[1], Gakushi Kawamura[2], Eun-Nam Bang[3], Suk-Ho Hong[3], Zhongshi Yang[1], Guang-Nan. Luo[1*]

[1] Institute of Plasma Physics, Chinese Academy of Sciences, China, [2] National Institute for Fusion Science, Japan, [3] KSTAR research center, National Fusion Research Institute, Korea

The plasma-facing components (PFC) are often castellated to improve the thermo-mechanical stability and to limit forces caused by induced currents in next generation of fusion machines like ITER or DEMO. More fuel retention is related to the safety issue for ITER. To study the issues of impurity transport and fuel accumulation in the gaps, series of exposure experiments with castellated tiles were performed in EAST, KSTAR, TEXTOR, DIII-D, and ASDEX Upgrade along with dedicated modeling [1-2]. In this paper, we focus on the deposition mechanisms inside gaps of castellated blocks with different shapes by comparison with results from KSTAR experiment.

3D Monte Carlo code PIC- EDDY [3] was used to simulate the carbon erosion, reflection and deposition inside and near tungsten gaps with different shapes in KSTAR. Due to the complex potential structure formed near the gap entrance, the sheath potential, electron field and ion flux distributions near and in gaps are simulated by a 2d3v particle-in-cell (PIC) method PICS2 code [4], which are used as input for PIC- EDDY as background particle sources. The surface composition information is stored for each surface cell independently and is updated after each simulation time step by TRIDYN code, which is coupled in PIC- EDDY. The databases of the energy- and species- dependent reflection coefficients calculated by molecular dynamics (MD) are used in the modeling.

Five different shapes of tungsten tiles were fabricated: conventional 'basic' rectangular shape, chamfered shape (ITER base design), double-chamfered shape, blocks with rounded edge, and trapezoidal shape. Hydrocarbon depositions were obtained along each sides and bottom of these types of gaps. For rectangular shape, the carbon deposition is in a range from 1.0×10^{15} atom/cm^2 up to 7.0×10^{15} atom/cm^2 along the gaps, which is consistent with the experimental result. But, very low hydrocarbon deposit on the shadowed side. The reason is the redistribution of sputtered particles from the plasma-wetted side at the high ion temperature. In the leading edge case, the dominant process of deposition is erosion. Ions can enter bottom of the toroidal gaps for their larmor radius of 0.4mm (less than the width of gaps) when the magnetic field line is parallel to the toroidal direction. There is no much difference between the blocks with rounded edge and oblique edge. The code verified by experimental results for different structures of tungsten tiles is to reveal physical processes and mechanisms on impurity deposition near and inside the gaps, and then will give valuable information on the deposition inside the gap of ITER castellated tiles.

References

[1] E. Bang, S.H. Hong, K. Kim, H. Kim, Nuclear Materials & Energy, (2017).
[2] A. Litnovsky, V. Philipps, et al., Journal of Nuclear Materials, 367-370 (2007) 1481-1486.
[3] Q. Xu, Z. Yang, G.-N. Luo, Japanese Journal of Applied Physics, 54(9) (2015) 096201.
[4] G. Kawamura, N. Ohno, S. Takamura, Y. Tomita, Nuclear Materials & Energy, (2017).