Plasma-Wall Interaction Study towards the Steady State Operation

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Understanding of phenomena of plasma-wall interaction (PWI) is one of critical issues for achievement of a steady state operation of fusion plasma. Surface condition of plasma-facing material continues to change during plasma discharges due to radiation damage, erosion, redeposition, blistering and hydrogen absorption through PWI. It is necessary to develop in situ and real time measurement of the wall surface condition. As for particle control for steady state operation, hydrogen recycling is a key issue.

The global wall pumping rate was estimated using a global particle balance model. The wall temperature plays an important role of the hydrogen reemission of the wall. Wall saturation occurred when the wall temperature increased due to plasma heat load in TRIAM-1M. In the case of the low temperature wall, on the other hand, no wall saturation was observed until the ultra-long discharge with the duration of 5 h 16 min. At that time, continuous growth of the deposited layer was observed using in situ and real time monitor of the thickness of the deposited layer. Codeposition seems to attribute to the continuous wall pumping. In the initial phase ($t < 30$ s) of the long duration discharge, It was observed the correlation between the global wall pumping rate and the oxygen impurity flux, which may dominate erosion and deposition on the wall and the hydrogen retention property of the codeposited layer. Based on the results in TRIAM-1M, the “hot wall” project has proceeded for the steady state particle control in QUEST.

In order to understand PWI phenomena, it is indispensable to measure and evaluate the material surface condition. We have developed a compact PWI simulator named APSEDAS (Advanced PWI Simulation Experimental Device and Analysis System) to demonstrate in situ and real-time measurement of material surface conditions and to study PWI process such as hydrogen retention and bubble formation. In situ and ex situ measurements of the optical reflectivity of the W has been made to study the surface modification of the W due to the low energy He plasma ($E \sim 28$eV, $\Gamma \sim 8.7 \times 10^{22}$ He^+ m^{-2} s^{-1}) irradiation. In situ measurement of the optical reflectivity with $\theta = 75$ degree revealed that the optical reflectivity of the W sample increased by ~6 % and decreases to the original level at the fluence of $\sim 3 \times 10^{24}$ He^+ m^{-2}, and then increased again by ~6 % with the fluence up to $\sim 1.6 \times 10^{26}$ He^+ m^{-2}. The calculation using a model of the multiple-reflection in the modification region suggests that the thickness of the modification layer of the W sample is larger than 70 nm. Moreover, hydrogen retention of W has been studied in APSEDAS.