Estimation of Dynamic Retention with Fast Ejecting System of Targeted Sample (FESTA) in QUEST

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Steady state operations (SSO) are important for a magnetic confinement nuclear fusion power plant, and static and dynamic retention of fuel particles, hydrogen and its isotopes in plasma facing walls (PFWs), must be investigated to achieve SSOs. Lately, due to the introduction of metallic wall, a dramatic reduction of wall-stored fuel particles after plasma discharges was reported at Joint European Torus, indicating that dynamic retention becomes dominant and plays a crucial role in the fuel particle balance. In QUEST (Q-shu University Experiment with Steady Spherical Tokamak) which is equipped all metallic walls, static retention in PFWs has been quantitatively measured until now, while dynamic retention was only estimated by nuclear reaction analysis [1] whose conditions are completely different from real high temperature plasma.

In this research, to measure the local dynamic retention from plasma-exposed specimens in-situ, a newly developed Fast Ejecting System of Targeted sAmple (FESTA) has been used. The specimen set-up on the stage in the test chamber of FESTA is picked up and then delivered inside the QUEST chamber with a movable arm which is connected to a telescopic device. After plasma exposure, the specimen is extracted and then be put on the specimen stage in the test chamber which will be isolated by two gate valves after the removal of the movable arm. The temperature of exposed specimens can be monitored by the thermocouples on the specimen stages during the measurements. Such a series of operation can be carried out within 10 s at the desired time programmed by LabVIEW [2].

A test specimen made of type 316L stainless steel (316L SS) was exposed to plasma of which duration is 1000 s using FESTA. With the help of the background model [2], the hydrogen flux released from the plasma-exposed specimen was measured and two released hydrogen flux peaks were observed. Because of the existence of oxide layer on the 316L SS specimen and to understand the observations, a quantitative analysis has been executed with a diffusion equation of hydrogen, including surface recombination, trapping, and de-trapping effects. As a result, the released hydrogen flux from the plasma-exposed specimen can be simulated due to the newly developed two-layer model. The simulation indicates that the first peak corresponds to the desorption caused by surface recombination which is quite sensitive to the temperature of the specimen, and the second peak is from hydrogen atoms trapped in the substrate of the specimen.

[1] K. Hanada, et al., Nucl. Fusion 59 (2019) 076007
[2] Q. Yue, et al., Plasma Fusion Res. 15 (2020) 240201