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Direct measurement of dynamic retention from plasma exposed stainless steel type 316L specimen using Fast Ejecting System of Targeted Sample (FESTA) on QUEST

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The hydrogen isotopes retention and subsequent excessive desorption (dynamic retention) on the plasma facing walls (PFWs) frequently lead to density runaway and plasma termination due to R > 1, where R means recycling ratio. This issue has a significant impact on steady state operation (SSO) of fusion experimental devices. Recently, the use of metallic materials such as tungsten in PFWs on fusion experimental devices has been promoted to reduce the wall-stored hydrogen isotope. This is likely to induce the excessive desorption connect to R >1 and further investigation of dynamic retention during plasma discharge in fusion experimental devices is highly addressed. However, the measurement of the dynamic retention in fusion experimental devices is quite limited.

In this research, therefore, a device named FESTA (Fast Ejecting System of Targeted sAmple) has been developed to measure the dynamic retention of hydrogen during plasma discharge in QUEST [1]. The FESTA operation is performed by the pre-programmed way using LabVIEW. A prepared specimen is firstly set in the FESTA chamber before the plasma discharge and a FESTA arm to pick up a specimen goes into the chamber. Using the arm, the specimen is inserted into the QUEST plasma chamber to be exposed to plasma. During plasma discharge, the specimen can be extracted from plasma exposure when the arm takes it back and leaves it in the FESTA chamber. After the FESTA arm returns to the original position, the FESTA chamber is isolated by gate valves and the hydrogen desorption from the specimen is measured by a quadruple mass analyzer.

A stainless-steel type 316L specimen was serially exposed to the same plasma lasting 910 seconds three times with a fixed interval of 70 minutes at room temperature (plasma current Ip ˜ 2 kA, RF power P ˜ 25 kW, electron density ne ˜ 1×1017 m-3, hydrogen influx Γin ˜ 1.3×1017 m-2s-1). To eliminate the influence of desorption from the FESTA chamber, which is also being exposed to the plasma, a background model was developed [1]. The background model could reconstruct the hydrogen desorption from the chamber wall during the FESTA operation without a specimen. Finally, it is found that FESTA can measure the hydrogen desorption and the dynamic retention from the plasma-exposed specimen made of stainless-steel type 316L. It is observed that the dynamic retention from the specimen was increasing shot by shot, which indicates that shot history plays an important role on fuel particles, which could be explained by a diffusion-trap model with hydrogen barrier between the surface oxide layer and the material substrate developed by thermal desorption spectrum measurement of the specimen. The property of the stainless-steel type 316L around room temperature has a significant impact on fuel particle balance during long pulse operation in QUEST.

[1] Q.Yue, et al Plasma Fusion Res. 15 (2020) 240201

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