§18. Hydrogen Retention and its Surface Temperature Dependence for Moving-surface Plasma-facing Components in Vehchle-1

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1. Introduction

For long pulse operation of the tokamak plasma it has been found that the difficulty of the particle control is ascribed to the temporal change in re-emission and retention properties on the PFCs, which is ascribed to the heat load distribution on them. It has been also reviewed that in long pulses the particle recovery after shot is independent of the retained fuel, leading to a significant wall inventory build up in contrast with short pulses].

Thus, the understanding of the re-emission and retention processes of H_2 from and in tungsten as a function of ion fluence and surface temperature is essential for not only the tritium inventory, but for the density control in steady state reactors. The purpose of this work is to study dynamic behavior of hydrogen re-emission and retention in inert gas sprayed tungsten exposed to plasmas in "continuous exposure" mode and "cyclic exposure with a recovery time" mode at target temperature range of 500 K – 900 K.

2. Experimental procedure

A linearly magnetized steady state plasma facility VEHICLE-1 is used for plasma exposure experiment. Using the 2.45 GHz power source steady state hydrogen and helium plasmas are generated at second harmonic electron cyclotron resonance heating. A tungsten coated stainless steel disk of 3 mm in thickness and 28 mm in diameter is exposed to ECR plasma. Tungsten with a thickness of ~ 0.5 mm is coated by an inert gas plasma spray method on this disk. In order to control the exposure scenario both the shutter on/off and RF on/off techniques are adopted. The pneumatic Mo shutter is used to keep the plasma and environment conditions constant and for latter case, the gas condition is fixed. A quadruple mass spectrometer (QMS) is housed in a differentially pumped vacuum chamber separated from the main chamber by an orifice creating a pressure ratio of about 100-to-1. The H_2 partial pressure P_{H2} and others (P_{H2O}, P_{CH4}, P_{CO2} etc.) are recorded. During the plasma exposure P_{H2} is ~ 3×10^{-5} Torr, P_{H2O} ~ 3×10^{-8} Torr and P_{CH4}~ P_{CO2}~3×10^{-9} Torr. As it has been pointed out, the inventory measured by TDS depends very critically on the time between the exposure termination and the onset of TDS due to the decrease of the solute inventory after the termination of exposure. Without time delay after plasma exposure or air vent post-exposure TDS and isothermal desorption measurements can be performed by using the heater.

3. Results and summary

In order to simulate the pulse tokamak operation and to understand the dynamic response in reemission and retention during the whole cycle the "cyclic plasma exposure with the recovery time" mode is used. The partial pressure measurement using differential pumped QMS is performed to follow the pressure change responding to the cyclic exposure. It is found that apparent reemission is triggered at least within 20 s by both T_s rise and plasma exposure, as shown in Fig.1. Immediately after the exposure is switched off, apparent reemission turns to apparent retention during the T_s decay phase. In contrast to the above result, no reemission and dynamic retention are observed in the wide range of T_s under the condition $\Delta T_s <$ 40 K, zero bias voltage and negative ∇T_s .

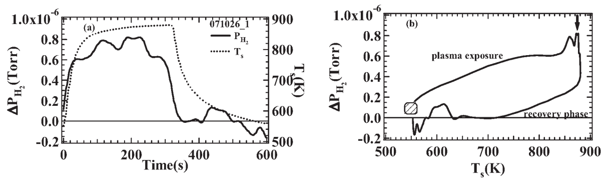

Fig.1 Using a boxer type averaging,$\langle P_{H2}\rangle$and $\langle T_s\rangle$ are averaged during each cycle (a) and a hysteresis relation between $\langle P_{H2}\rangle$ and $\langle T_s\rangle$ (b). A shaded point indicates the start of exposure and an arrow the end of the exposure.

The difference in hydrogen retention for two continuous and cyclic modes is not clear within reproducibility, though a drastic difference between single long pulse and shorts pulses is seen in the real tokamak operation. The helium plasma assisted TDS is also used to measure additional H retention during the thermal release measurement. The bombarding energy of He is < 25 eV. Observed retention is three to six times larger than that without using helium exposure at the same H fluence. This enhanced retention may relate to the small bubbles

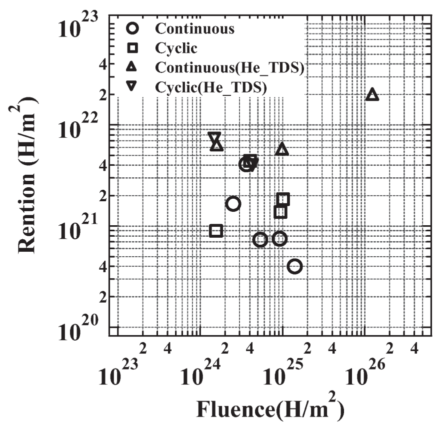

Fig.2 TDS and isothermal measurements of H retention at T_s from 570 to 900 K, as a function of H^+ fluence. Two exposure scenarios are compared. In order to evaluate the retention of H remained by limited temperature of 900K He bombardment is done at the zero bias voltage.

1. K. Okamoto et al, 'Hydrogen retention and release in and from tungsten exposed to ECR plasma' submitted to 18th PSI conference (2008)