

### §34. Microwave-plasma Irradiation Effects on Bubble Formation in APS W Due to in Vehicle-1

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**Abstract** Hydrogen retention and pressure variation in and from the inert gas plasma sprayed tungsten (IPS-W) exposed to plasmas are described. Two kinds of plasma irradiation scenarios are investigated in continuous and cyclic exposures. The H retained fluence at the surface temperature  $T_s$  of 470 ~ 900 K was evaluated in the range of  $4 \times 10^{20}$  -  $2 \times 10^{22}$  H/m<sup>2</sup> for the bombarding fluence of  $1 \times 10^{24}$  -  $1 \times 10^{26}$  H/m<sup>2</sup> under continuous exposure condition. For the cyclic exposure, it is found that if  $\Delta T_s > 100$  K during exposure, the apparent reemission (pressure increase) is triggered by both  $\Delta T_s$  and irradiation itself, and just after the exposure it turns to apparent retention (pressure decrease). However, for  $\Delta T_s < 40$  K no apparent reemission and retention are observed in the cycle. This fact suggests that the hydrogen reemission is enhanced during the exposure via the surface recombination process depending on  $\Delta T_s$  or  $T_s$  gradient across the specimen[1,2].

#### Motivation and Experiments

Plasma facing material (PFM) used for International Thermonuclear Experimental Reactor (ITER) has been reviewed from a fusion reactor PFM point of view. Tungsten is a candidate material since it has a high threshold for sputtering as well as a very high melting temperature. Furthermore, for particle recycling, it has been also known that the release of H<sub>2</sub> from the tungsten surface is dominated by its endothermic properties in TEXTOR. For the surface temperature  $T_s$  dependence of the hydrogen retention in tungsten, there are several reports. The tritium retention has a maximum at intermediate temperatures, interpreted by enhanced diffusion in the implanted range, in 100 eV triton implantation experiments, and relatively lower temperature (~600 K) needed for release of deuterium is ascribed to smaller trapping energy (~1.5 eV) compared with graphite. The fluence dependence (up to  $10^{25}$  D<sup>+</sup>/m<sup>2</sup>) shows that retention at 500 K is larger than that at 300 K and no saturation is observed at 500 K. The deuteron profile measurements in tungsten show that they diffuse deep into tungsten whose range exceeds the implantation range by two orders of magnitude and suggest an enhanced diffusion mechanism. The blister is formed as  $T_s$  increases and the size reaches ~ 30 micron. However, no blister formation is observed at  $T_s$  above 680 K. It has been suggested that hydrogen will accumulate in tungsten if the recovery time between two shots is shorter than the time needed for the release of solute hydrogen. Actually, for long pulse operation of the tokamak plasma it has been found that the difficulty of the particle control is due to the temporal change in re-emission and retention properties from and in the plasma facing components PFCs, on which

the heat load are deposited non-uniformly. 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, understanding of the re-emission and retention processes of H<sub>2</sub> from and in tungsten as a function of ion fluence and surface temperature is essential for not only the tritium inventory, but also for the density control in steady state reactors. In order to control the shot history or shot accumulation effects, dynamic aspects of reemission and retention from and in the PFCs should be clarified. Two kinds of exposure modes, namely "continuous exposure" and "cyclic exposure with a recovery time", are examined for IPS-W whose surface temperature is within the range of 470 - 900 K. The purposes of this work are to study hydrogen retention in the former mode at the particle flux  $1 \times 10^{21}$  -  $8 \times 10^{21}$  H/m<sup>2</sup>/s and in the latter mode to investigate the pressure variation as a function of  $T_s$  in ECR plasma.

#### Summary and Conclusion

In order to simulate the pulsed 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. 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  $\nabla T_s$ . The difference in hydrogen retention for two continuous and cyclic modes is not clear, though a drastic difference between single long pulse and shorts pulses is seen in the real tokamak operation. The He plasma exposure is used to evaluate H retention after H plasma exposure. Observed retention is three to six times larger than that without using helium exposure at the same fluence.

[1] H. Zushi et al., "DYNAMIC RESPONSE OF HYDROGEN REEMISSION AND RETENTION FROM AND IN INERT GAS SPRAYED TUNGSTEN EXPOSED TO ECR PLASMS" FST **55** 9-14 (2009)

[2] K. Okamoto, H. Zushi et al., "Surface Temperature effects on the Retention and Pressure Variation in Continuous and Cyclic Plasma Exposures on the Tungsten", JNM **390-391** 671-675 (2009)