§35. Dynamic Response of Hydrogen Reemission and Retention from and in inert Gas Sprayed Tungsten Exposed to ECR Plasms in

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Abstract: Hydrogen reemission and retention from and in the inert gas plasma sprayed tungsten (IPS-W) exposed to the plasma are described. Two kinds of irradiation scenarios are investigated in continuous and cyclic exposures. In the later a recovery phase exists between plasma exposure phases, simulated to the regular tokamak discharges. The H retention at the surface temperature T_s of 600 ~ 900 K was evaluated from 4×10^{20} m^{-2} to 2×10^{22} m^{-2} at the fluence from 1×10^{24} m^{-2} to $1\times$ 10^{26} m^{-2} under continuous exposure conditions. For the cyclic exposure, two cases associated temperature variation during the cycle, large ΔT_s> 100 K and small < 40 K, are investigated. The temperature rise ΔT_s dependence of the reemission and retention is observed. When ΔT_s > 100 K, the apparent reemission is triggered by both ΔT_s and irradiation itself, and then after the exposure stops it turns to apparent retention. However, for ΔT_s < 40 K no 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 ΔT_s or T_s gradient across the specimen. [1,2].

Motivation and Experiments

Plasma facing material (PFM) used for International Thermonuclear Experimental Reactor (ITER) have been reviewed from a fusion reactor plasma facing material PFM view. Tungsten is a candidate since it has a high threshold for sputtering as well as a very high melting temperature. Since tungsten is known to retain much less hydrogen atoms, two aspects, particle reemission and retention has to be clarified in the tokamak experiments under the severe particle and heat load conditions. In TEXTOR, particle recycling experiments using a tungsten limiter have been performed and it was concluded that the release of H_2 from the tungsten surface was dominated by its endothermic properties. In this experiment the surface temperature T_s is in the range of 1000 - 1500 K, and no T_s dependence is observed. There are several reports for the T_s dependence of the hydrogen retention in tungsten from the laboratory experiments. The fluence dependence (up to 10^{25} D^+/m^2) of the retention 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. The diffusion range exceeds the implantation range by two orders of magnitude and this fact suggests an enhanced diffusion mechanism, which is an open question at present. The blister on tungsten due to hydrogen bombarding 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 exposure 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 ascribed to the temporal change in re-emission and retention properties on the PFCs. 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.

Summary and Conclusion

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. 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 ΔT_s < 40 K, zero bias voltage and negative ∇T_s. 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 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)