# §22. Observation of Hydrogen Permeation in LHD and Evaluation of Wall Leakage for DD Experiments

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Hydrogen permeation through plasma-facing walls in magnetic confinement device has attracted attention from view point of tritium leakage. The main parameter in estimating the permeation is the recombination coefficient, a rate constant for hydrogen atoms to form molecules. For this purpose, a measurement system was installed in a tokamak device QUEST and hydrogen plasma driven permeation during the plasma discharge was observed at 2008. In the present work, the recombination coefficient will be estimated from transient behavior or the permeation flux.

The system consists of two vacuum systems, upstream and downstream ones, separated by a nickel membrane. A shutter baffle is located between the probe and the plasma. The thickness of the Ni probe membrane is 30 μm. Hydrogen permeation is observed by a quadrupole mass analyzer (QMA) with magnetic shield, set in the downstream chamber. Permeation measurements were also carried out during the ECR discharge conditioning plasmas obtained at very first day of the second experimental campaign. During these measurements, the chamber pressure was kept fixed using a feedback controlled piezoelectric valve. The plasma discharge periods were kept ~30 s for each shot. The RF power of ~4 kW using the 2.45 GHz RF system was utilized to produce discharge conditioning plasma. The permeation measurements were used to understand wall behavior during the wall conditioning phase. $H_\alpha$ line and hydrogen molecular spectrum (Fulcher-α band) were used to characterize the overall hydrogen species. Figure 1 shows the time integrated $H_\alpha$ measurement i.e. $Q_\alpha$ during these discharge shots. The plasma was produced with three chamber pressures (I) $2\times10^{-5}$, (II) $6\times10^{-5}$ and (III) $2\times10^{-4}$ Torr as depicted by three roman letters in figure. It was observed that the $H_\alpha$ was reduced with increasing pressure. This was possibly due to the fact that the RF power (4 kW) was not sufficient to ionize the gas. However the $H_\alpha$ level was nearly constant under a fixed pressure at a TMP head, which suggested the constant atomic flux on the chamber walls.

On the other hand, $H_2$ spectral (Fulcher–α) fluence ($Q_{H2}$) was enhanced with increasing chamber pressure as shown in fig. 2. It suggested that the numbers of molecules were increasing with chamber pressure. Surprisingly, $Q_{H2}$ was also increased during the discharges keeping the same pressure. As the pressure was fixed, the rise of $Q_{H2}$ was due to the rise of molecular hydrogen released from the wall. Simultaneously, the permeation measurements were also carried out and the estimated values of $Q_{perm}$ were compared with spectral fluences (fig. 2 ). It was observed that $Q_{perm}$ increased with raising the chamber pressure but decreased during the shots made at fixed pressures. This behavior of $Q_{perm}$ was quite opposite to that of $Q_{H2}$. Considering constant incident atomic flux as suggested by fixed $H_\alpha$ signal, the decreasing of $Q_{perm}$ could be explained by increasing the recombination coefficient at upstream side of the membrane i.e. $k_u$. It should be noted that the recombination coefficient generally increases by cleaning a surface, which was obviously the case during the discharge conditioning plasma. Hence the reduction of $Q_{perm}$ seems to be due to the cleaning of the membrane via increasing the recombination coefficient. In a similar way the rise of $Q_{H2}$ might be due to the rise of recombination coefficient on the chamber walls because the hydrogen released in form of molecules was increased with plasma shots even at fixed chamber pressures. The measurement of atomic flux was also utilized for understanding the dynamic character of the walls during the ECR discharge conditioning plasma. The permeation measurements along with spectral (atomic and molecular) fluences have depicted the alterations in the recycling behavior of the walls. These measurements suggested surface cleaning and the changes in the recombination coefficient and recycling behavior of the walls. The variation of the recombination coefficient on the permeation membrane under high atomic flux (high pressure) and longer discharge shots may be disadvantage for considering the permeation technique for the measurement of the atomic flux, but in situ annealing of the membrane at high temperatures or a selection of proper materials can solve such problems.

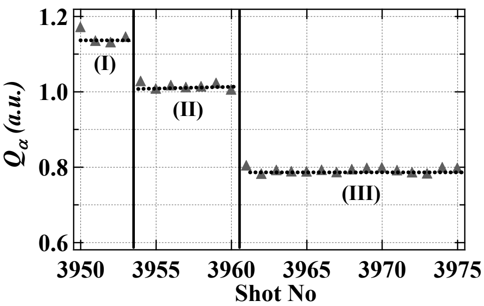


Fig. 1. $Q_\alpha$ vs. shot no. during discharge cleaning plasmas. Roman numbers I, II and III correspond to the fixed chamber pressures of $2\times10^{-5}$, $6\times10^{-5}$ and $2\times10^{-4}$ Torr respectively.

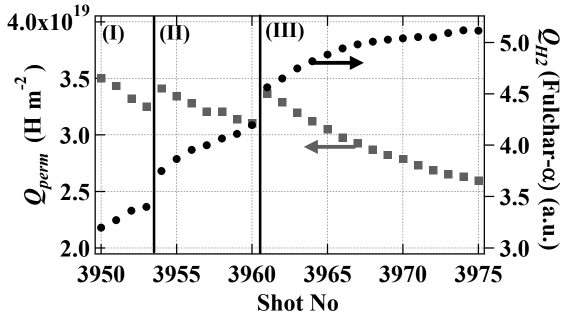


Fig. 2. $Q_{perm}$ and molecular spectral fluence ($Q_{H2}$) vs shot no. during similar shots.