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

Takagi, I., Ueyama, Y., Imade, R. (Kyoto Univ.), Zushi, H., Bhattacharyay, R., Ryokai, T., Hisano, Y., Tashima, S. (Kyushu Univ.), Hatano, Y. (Toyama Univ.), Yukio, N., Sagara, A., Ashikawa, N.

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. The recombination coefficient strongly depends on plasma conditions such as particle flux, ion temperature and impurity amount, so it largely scatters among the laboratory-scale experiments. It is important to observe the permeation in plasma devices of which the plasma conditions are well known and to relate the recombination coefficient with the plasma parameters. As the first step to the present work, a measurement system is installed in a tokamak device QUEST[1)] and hydrogen plasma driven permeation[2)] during the plasma discharge is observed.

QUEST is a medium sized spherical tokamak, whose radius and height are 1.4 m and 2.8 m, respectively. The vacuum chamber is made of type 304 stainless steel. The measurement system, called a 'permeation probe', is installed on the mid plane to view the plasma horizontally.

As shown in Fig.1, the probe consists of two vacuum systems, upstream and downstream ones, separated by a nickel membrane. In order to prevent direct incidence of impurities on Ni surface, a shutter baffle, is located between the probe and the plasma. The thickness and the temperature of the Ni membrane are 30 μm and 523 K, respectively. The position of Ni is 0.3 m behind the QUEST wall. Hydrogen permeation is observed by a quadrupole mass analyzer (QMA) with magnetic shield, set in the downstream chamber.

Hydrogen plasma is initiated by 2.45 GHz microwave using electron cyclotron resonance with 4 kW power. Fast camera observation indicates that the plasma extends towards the side wall, but this area seems to be limited until the second harmonic layer (0.73 m). The ordinary mode is injected with respect to the toroidal field. Hydrogen gas is puffed just before the RF discharge. The base pressure is around 0.1 μtorr and pressure increase by gas puff is kept to a few μtorr during the discharge. Hydrogen Balmer line H_α is measured horizontally along the major radius.

Figure 2 shows time evolution of the permeation flux when the RF is turned on at 0.4 s and subsequent discharge continues for 0.03 to 1.1 s. In case of 1.1 s discharge, the evolution curve rises around 2.5 s, reaches a peak at 7.5 s and then decreases for 40 s. The rise time does not depend on the discharge time and it agrees well with a lag-time of $d^2/6D$, where d and D are the membrane thickness and the hydrogen diffusion coefficient, respectively. When the gas is puffed without any discharge, no permeation is observed. The total amount of the permeation flux Q is almost proportional to the square root of the discharge time. It is concluded that the plasma driven permeation is clearly observed and the permeation is limited by the diffusion process.

The value of Q is nearly proportional to the time-integral of H_α intensity. When the shutter is closed to prevent direct incidence of hydrogen particles to the probe, no difference in the permeation flux is observed. These suggested that a large number of atomic hydrogen from the plasma, reflected by inner surface of the vacuum wall, mainly contributes to permeation.

Under the fixed discharge time of 1.1 s, Q slightly increases with the amount of puffed gas G and there seems to be a large intercept at G=0. This is probably because the number of hydrogen recycled between the plasma and the wall is much larger than that introduced by the gas puff.

The plasma driven permeation is successfully observed by the permeation probe installed in QUEST and some information such as the limited process of permeation, hydrogen particle reflection and recycling is obtained. Quantitative study on recombination and related processes will be conducted as the next step.

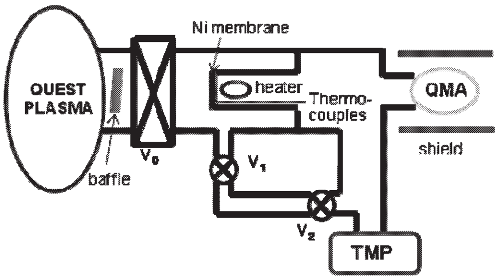

Fig. 1. A measurement system of plasma driven permeation

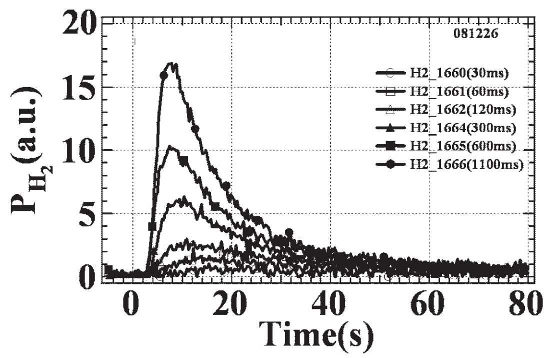

Fig. 2. Time evolution of the permeation flux after the plasma discharge for 0.03 to 1.1 s

1) Hanada, K. et al.: 22nd FEC (2008)
2) Takagi, I. et al.: Fusion Technol. **25** (1994) 137