§65. First Wall Particle Flux Measurements by an F82H Permeation Probe in QUEST

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In magnetic fusion power devices, hydrogenic particles will escape from the confinement region and then migrate through the first wall by plasma-driven permeation (PDP). Hydrogen isotopes (D and T) flowing into the blanket by PDP will hinder the recovery of tritium and will probably necessitate isotope separation. Tritium permeation through the first wall may raise reactor safety issues as well. It is highly desirable to perform the measurements of particle flow to the wall in fusion devices. Reduced activation steel alloys such as F82H are the candidate materials for the first wall of DEMO reactors. In our previous studies, permeation parameters including solubility, diffusivity and recombination coefficient have been measured for F82H in the temperature range from 150 to 520 ℃ in a steady-state laboratory-scale plasma device: VEHICLE-1.[1)] In the present work, membrane samples prepared in the same way as those used in VEHICLE-1 are installed on a permeation setup in the spherical tokamak QUEST,[2)] so that the surface conditions for all the samples are assumed to be the same and the hydrogen transport parameters taken in laboratory experiments can be used to analyze the measurement results in QUEST.

Hydrogen permeation experiments have been performed for the low temperature, low density slab plasmas in discharge cleaning experiments using the 2.45 GHz and the 8.2 GHz sources. The slab plasma means plasmas produced in the electron cyclotron resonance region without poloidal field (i.e., no closed flux surfaces), as shown in Fig. 1(a). The permeation probe has been installed near the mid-plane and the permeation membrane made by F82H is 35 mm away from the outboard wall in the radial direction. A resistive heater is set behind the sample so that the membrane temperature can be kept in a range of 240-300 ℃. The temperature is measured by a thermocouple attached to the downstream surface. The hydrogen partial pressure is measured by a quadrupole mass spectrometer (QMS), which has been calibrated by a hydrogen standard leak, as shown in Fig 1(b).

Shown in Fig. 2 are the Hα intensity and permeation flux data for two 900 s discharges with different heating methods. The long-pulse plasmas are maintained by the 2.45 GHz RF source with a power of 4 kW. For shot #21446, additional 8.4 GHz ECR heating (25 kW, 0.4s width) is conducted throughout the discharge with a frequency of 0.1 Hz. Permeation flux measurements show that without 8.2 GHz RF heating, the steady-state PDP flux decreases by ~13% for F82H. Due to the lack of plasma temperature and density data, the time-integrated Hα intensity ($Q_{H\alpha}$) is used as a measure to estimate the particle flux to the wall. At t=900 s, where t is the time, the value of $(Q_{H\alpha})^{1/2}$ for shot #21446 is higher than that of shot #21447 by a factor of ~1.41, while the permeation flux ratio of the two discharges is ~1.13. Data roughly agree with the theoretical prediction for the permeation flux when plasma-driven permeation is recombination-diffusion (RD) limited.[3)]

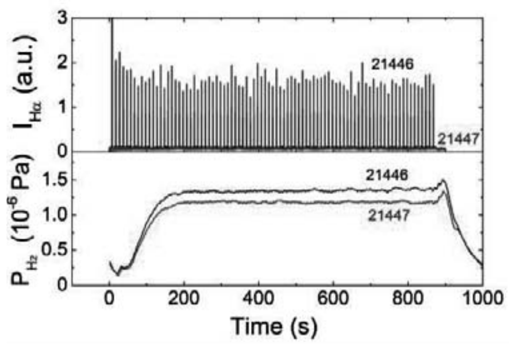

Fig. 2. PDP through F82H membrane w/ and w/o the 8.2 GHz RF plasma heating source.

1) Zhou, H. et al.: Paper presented at the ICFRM-16, Beijing, China, Oct. 20th -26th, 2013.
2) Hanada, K. et al.: Plasma and Fusion Research **5** (2010) S1007.
3) Doyle, B.: Journal of Nuclear Materials **111&112** (1982) 628.

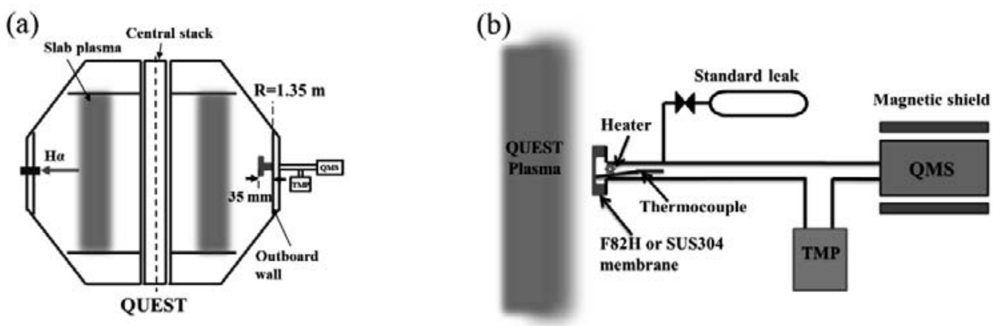

Fig. 1. Schematic diagrams of (a) the permeation probe setup in QUEST and (b) the details of the permeation flux measurement system.