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Development of an in-situ calibration method for permeation probes for atomic hydrogen detection in fusion devices.

Kuzmin Arseniy[1], 蓮尾 昌裕 [1], 四竈 泰一 [1], 藤井 恵介 [1], 門 信一郎 [1],
小林 政弘 [2], 花田 和明 [3]
Arseniy Kuzmin[1], Masahiro Hasuo[1], Taiichi Shikama[1], Keisuke Fujii[1], Shinichiro Kado[1],
Masahiro Kobayashi[2], Kazuaki Hanada[3]
[1]Kyoto University, [2] National Institute for Fusion Science, [3]Kyushu University
[1]京都大学, [2]核融合科学研究所, [3]九州大学

Results of the radial distribution scan of incident atomic hydrogen flux F to the walls in QUEST tokamak in inboard null (IL) configuration discharges are shown in Fig. 1. a. F is calculated from the measured permeation flux J, shown in Fig. 1. b, using a recombination coefficient for downstream side of the membrane from [1]. The upstream recombination coefficient is estimated from the decay phase of the permeation curve, where F = 0.

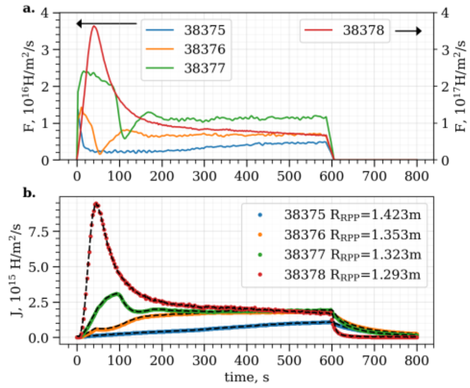

Fig. 1. Permeation probe results for IL discharges in QUEST.

In Fig. 2, the radial distribution of the calculated F and ion flux, Γ_{ion}, calculated from a Langmuir probe ion saturation current, are shown. One can notice that both profiles rapidly decay behind the radiation shield, however the significant F is detected far behind the vacuum port walls.

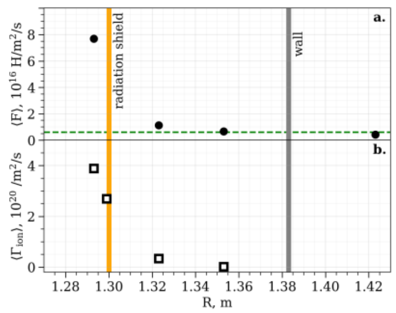

Fig. 2. Radial distribution of average F and Γ_{ion}.

It is noticeable that the absolute value of F is much smaller compared to Γ_{ion}. One can expect the opposite, since permeation probe detects both hydrogen ions and atoms. There are several possible reasons for this, most important is the H reflections and different recombination coefficients for our membrane compared to [1]. To resolve this disagreement, a calibration method for the permeation probe is developed. A small plasma device with two separate vacuum chambers is used to estimate F using two separate methods. One is by using a permeation probe with the same PdCu membrane, and another one - using H emission spectroscopy. Atomic hydrogen density is estimated from Balmer line emission with a help of hydrogen collisional-radiative model (CRM). Plasma parameters for CRM are scanned with a movable Langmuir probe, shown in Fig. 3.

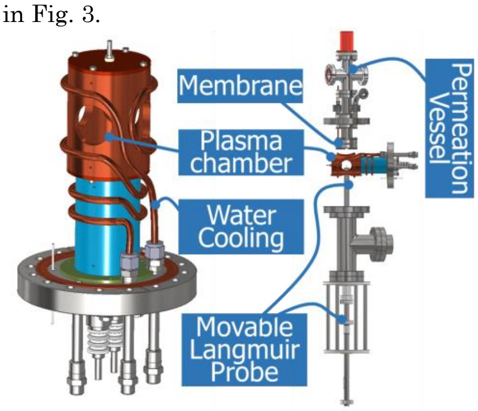

Fig. 3. Schematic view of the plasma source (left) and overview of the apparatus.

Preliminary results of the permeation experiments are shown in Fig. 4. One can see that the level of the plasma driven permeation (PDP) is comparable to that in QUEST, ~ 10^{16} H/m²/s. The gas driven permeation (GDP) is present in our set-up, but its level is much smaller than that of PDP (①and ③ in Fig. 4). Notice the immediate increase of F due to atomization on the hot filament, used for plasma production (Fig. 4, ②).

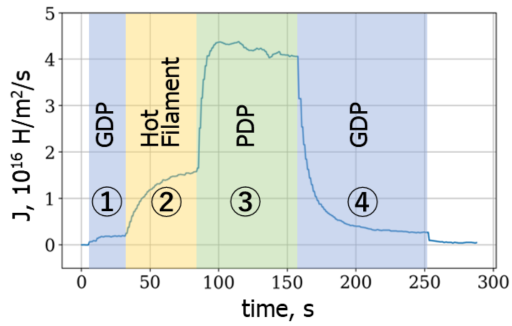

Fig. 4. Time evolution of J in the new apparatus.

F, estimated with these two independent methods are compared. The diffusion model is then updated so that both methods produce the same result.

[1] M. Onaka, et al., Nucl. Mater. Energy 9, 104-108 (2016).