§72. First Wall Particle Flux Measurements by a VPS-W Coated F82H Permeation Probe in QUEST

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In our previous study, first wall particle flux measurements in the QUEST spherical tokamak have been conducted, using a permeation probe that employs a first wall candidate ferritic steel F82H as the membrane [1]. The measurement results have been compared to the data taken from a laboratory-scale linear plasma device VEHICLE-1. It has been found that even for a 5 mm F82H membrane, the hydrogen permeation fluxes by plasma-driven permeation (PDP) and gas-driven permeation (GDP) can be as large as 8.0 x 10^{12} and 8.4 x 10^{14} H/cm^2/s at ~500 ℃ [2], which is undesirable from the viewpoint of achieving high-confinement via plasma-wall boundary control. Therefore, there is a need for surface coating as a hydrogen permeation barrier. Tungsten has been proposed as a candidate plasma-facing material for future fusion devices because of its beneficial properties, including high melting point, low sputtering yield and low hydrogen retention. In the present work, hydrogen PDP experiments through vacuum plasma-sprayed tungsten (VPS-W) coated F82H have been conducted in both QUEST and VEHICLE-1.

Fig. 1 shows a SEM image of VPS-W coating surface. The W coatings are deposited at ~600℃ and blast treatment has been carried out for the F82H steel surface before VPS process. The average size of W powder particles is ~25 μm. It is shown that VPS-W coating has an inhomogeneous microstructure, i.e., a mixture of disorganized areas composed of large unmelted W particles, fine randomly melted W areas and void regions (or porosity). Void regions or pores are observed primarily next to the unmelted particles. The average density of VPS-W coatings is ~90% of bulk W.

Shown in Fig. 2 (a) is the hydrogen PDP fluxes through a VPS-W coated F82H membrane and a bare F82H membrane measured in VEHICLE-1. At ~500℃, the steady state hydrogen PDP fluxes have been measured to be ~5.8× 10^{12} H/cm^2/s and ~1.6 x 10^{14} H/cm^2/s, respectively. Fig. 2 (b) shows that the tungsten coating decreases the hydrogen PDP fluxes by more than one order of magnitude at a temperature range of 250-550℃.

However, hydrogen permeation was not detectable during the discharge cleaning in the QUEST spherical tokamak at a membrane temperature of ~300℃ (Fig. 3). This is believed to be due to the low plasma density and the low probe temperature.

In the 2016 QUEST campaign, a thin film sputtering-deposited W coated F82H membrane will be used to continue PDP measurements for high temperature, high density plasmas in confinement experiments.

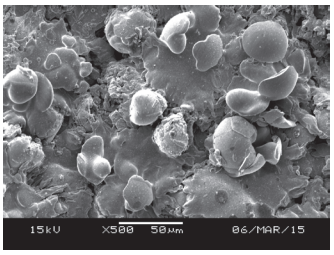

Fig. 1 SEM image of VPS-W coating surface.

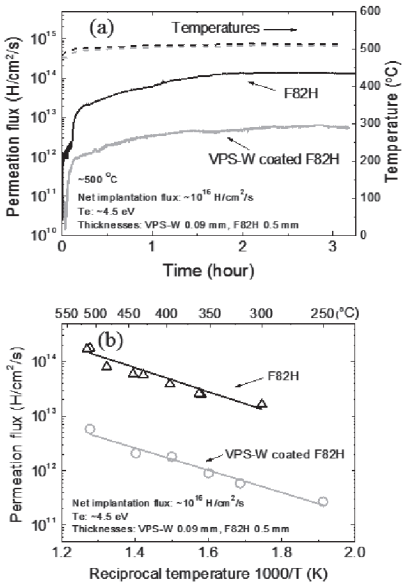

Fig. 2 Hydrogen PDP experiments in VEHICLE-1: (a) Hydrogen PDP breakthrough curves at ~500℃; (b) temperature dependence of hydrogen permeation fluxes through bare F82H and VPS-W coated F82H membranes.

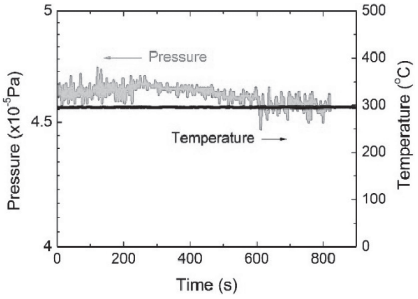

Fig. 3 Hydrogen PDP experiments in QUEST under plasma bombardment: net implantation flux ~10^{13} H/cm^2/s.

[1] H. Zhou, Y. Hirooka, H. Zushi, A. Kuzmin, Plasma and Fusion Research 9 (2014).

[2] H. Zhou, Y. Hirooka, N. Ashikawa, et al., Fusion Sci. Technol. 63 (2013) 361-363.