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デモ炉第一壁用低放射化合金の水素透過挙動
An Experimental Study on Bi-directional Hydrogen Permeation through the First Wall of a Helical DEMO Reactor

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Reduced activation ferritic steels (RAFSs) such as F82H are the candidate materials for the first wall of a helical DEMO reactor: FFHR [1]. From the viewpoint of thermal stress, the optimum thickness of the first wall is ~5 mm in which case the first wall will be subjected to bi-directional hydrogen permeation by the two mechanisms: one is plasma-driven and the other is gas-driven, the latter of which is due to the dissociation pressure of bred tritium. Despite their importance, these technical issues have never clearly been addressed in the fusion engineering research community. In the present work, plasma-driven permeation behavior through a reduced ferritic steel alloy F82H has been studied under some of the reactor-relevant conditions.

The linear plasma device VEHICLE-1 [2] has been installed with a plasma-driven permeation (PDP) experimental setup. Samples made of F82H and SUS304 are prepared in the same dimensions as those commercially available conflat flanges with an outer diameter of 70 mm, except that a circular area of ~35 mm in diameter inside the knife-edge is machined down to thicknesses between 1 mm and 5 mm. The membrane is heated by plasma bombardment up to around 250 ℃, and resistive heater radiation from the downstream side is added as needed to reach desired temperatures. Surface morphology of the membrane is observed by scanning electron microscopy (SEM) before and after PDP experiments.

Shown in Fig. 1 are the hydrogen permeation data taken from PDP experiments on 1, 2 and 5 mm thick F82H membranes at surface temperatures of 220 ℃ and 520 ℃, respectively. At 220 ℃, the steady state permeation flux ratio of F82H is inversely-proportional to the membrane thickness, indicating that permeation is diffusion-limited [3]. However, at a higher temperature (520°C) the effect of membrane thickness does not appear to be so straightforward as shown in the 220 ℃ case, which is presumably due to the different recombination conditions of upstream surfaces (Fig. 2) resulted from plasma bombardment.

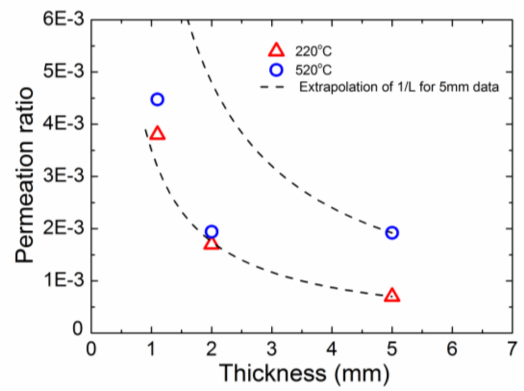

Fig. 1. F82H membrane thickness dependence of steady state PDP flux ratio.

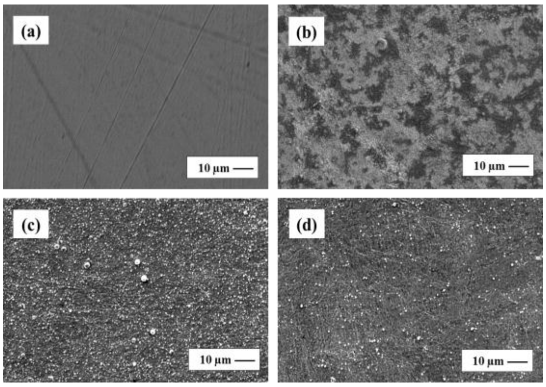

Fig. 2. SEM images of the upstream surface: (a) before exposure; (b) 1 mm thick membrane after PDP; (c) 2 mm thick membrane after PDP and (d) 5 mm thick membrane after PDP. The sample temperature during the experiment is ~520 ℃.

References

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