BEHAVIOR OF HYDROGEN IMPLANTED IN FIRST WALL MATERIALS

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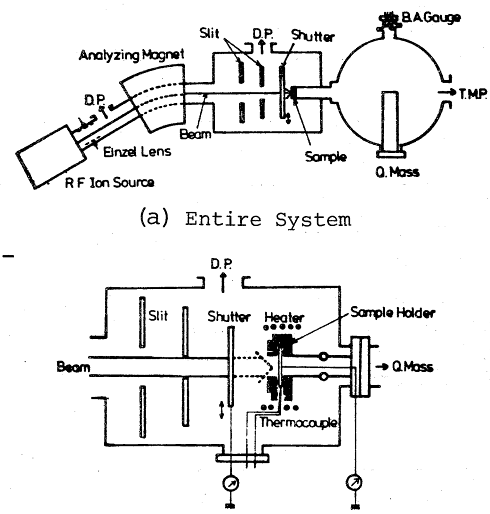
1. Introduction

It is one of the most important problem to estimate an inventory and/or recycling of tritium at the first wall material of CTR(Controlled Thermonuclear Reactor). In order to clarify hydrogen behavior in the first wall we have constructed a new apparatus for measurements of (1) diffusion and permeation, (2)re-emission and (3) thermal desorption of hydrogen isotopes implanted into metals. In the present paper the preleminary results of measurements of diffusion coefficient and permeation rate of implanted hydrogen under ion bombardment are reported.

2. Experimental

Figure 1 shows the apparatus for measurements of permeation rate and diffusion coefficient of hydrogen under ion bombardment. An analyzed deuetrium ion beam accelerated to 20 keV are injected to a specimen and deuterium which comes out to the other side by permeation is analyzed by a quadropole mass analyzer(Q-mass). Maximum flux of the beam is about 9×10^{18} $D^{+}/cm^{2} \cdot sec$ (1.4 A/m^{2}) and the residual gas pressure during implantation is about 8×10^{-5} Pa at the inlet side and 1×10^{-7} Pa at the outlet side.

The diffusion coefficient was determined by making least square fitting of permeation rate to the theoretical relation derived from Fick's law for two cases. The first was obtained from the increasing curve due to permeation of implanted deuterium at the outlet side immediately after beam-on(injection curve) and the second from the decreasing curve due to evolution of implanted deuterium at the outlet side shortly after beam-off (evolution curve). Details of analysis have been represented elsewhere.[1]



(a) Entire System

(b) Details of specimen holder

Fig.1 Apparatus for Measurements

3. Results and Discussion

Figure 2 shows the change of permeation rate with time under ion bombardment for Ni at various temperatures. When the beam was turned on(t=0), permeation rate of deuterium is increased to a maximum value, however, below 500°c the permeation rate decreased for further irradiation. The decreased permeation rate at nearly steady state is smaller than the maximum value by factor of one or two. Such decrease in the permeation rate of Ni has never been observed in ordinary hydrogen permeation measurement with gaseous charging method.[2]

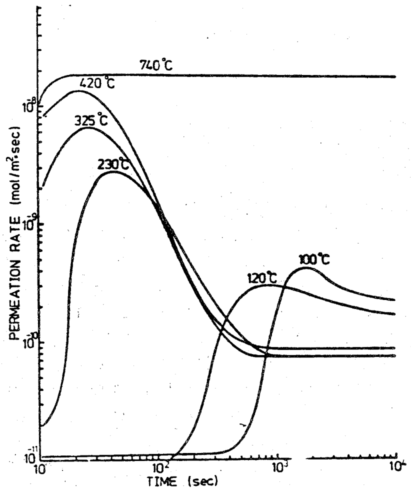


Fig.2 Change of deuterium permeation rate for Ni of 0.1 mm thick

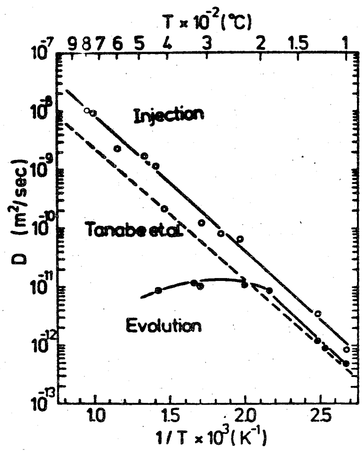


Fig.3 Diffusion coefficient of deuterium for Ni determined from injection, evolution and gaseous charging(Ref. 2)

The diffusion coefficients obtained from the injection curve for a virgin surface are in good agreement with those obtained from gaseous charging method(see fig. 3). However, the diffusion coefficients obtained from the evolution curve after nearly establishing the steady state are much smaller than those from the injection curve below 500°C. This suggests a strong effect of some radiation damage induced by ion implantation to the diffusion and permeation of deuterium in Ni.

Since permeation rate is represented by the product of the diffusion coefficient of the bulk and the surface concentration at the inlet side, the decrease in the permeation rate can be attributed to the decrease in diffusion coefficient and/or in surface concentration. Under the bombardment of energetic deuterium ions various types of irradiation defects such as vacancy, dislocation, interstitials and so on are produced near the projected range, and they are inferred to contribute to the decrease in permeation rate in following two ways. The first is increase of re-emission rate of implanted deuterium from the injected side. With increasing fluence, vacancies produced by irradiation at near surface region will lead to the formation of micro-pores or micro cracks piling up to the surface. Implanted deuterium is then easy to diffuse out from the surface of the inlet side, resulting the decrease of deuterium concentration at near-surface region. The second is trapping of deuterium by defects which have diffused into the deeper region than the projected range.

The second seems likely the case, because the diffusion coefficient obtained from the evolution which are considered to be influenced by radiation damages(see fig. 3) are remarkably smaller than those from the injection to a virgin surface. Above 600°C due to annealing of radiation damages, diffusion of deuterium is no more affected and permeation rate is not decreased. This also seems to suggest the less effect of re-emission rate from the injected side to permeation rate.

4. References

(1) N. Saitoh et al.: Technol. Repts. Osaka University , in press
(2) T. Tanabe et al.: Technol. Repts. Osaka Univ.,27(1977) No.1374.