§12. Carbon Deposition Effect on Membrane Pumping Properties

Nakahara, Y. (Hokkaido Univ.)
Nakamura, Y., Suzuki, H., Ohyabu, N.
Busnyuk, A., Alimov, V., Livshits, A. (Bonch-Bruevich Univ.)

Metal membranes of Ni, Fe, Pd and Va group metals (V, Nb, Ta) show a superpermeability to energetic hydrogen particles (atom, ions). Application of such membranes to a hydrogen particle exhaust in fusion devices is considered because the membranes let the suprathermal hydrogen particles pass through almost the same as an opening of the same area.

One of the problems for applying the membrane pump to the fusion devices is effect of impurity deposition on the membrane permeability to the hydrogen particles. When the membrane is used in plasma vessels, plasma-facing materials are sputtered by energetic plasma particles and the sputtered species may deposit onto the membrane surface. It is recognized that the membrane surface condition plays an important role for pumping hydrogen. Therefore, the membrane pump performance may be affected by the impurity deposition. In this study, carbon deposition effect is investigated by use of an UHV plasma device (detail of the device is written in a previous report[1]), because carbon is one of the most probable elements of the plasma-facing components in the fusion devices.

Dependence of hydrogen permeation rates on carbon deposition time is shown in fig. 1. The deposition time corresponds to the amount of deposited carbon onto the membrane surface. Although the process of carbon deposition is complicated and including some uncertainties, the deposition rate is roughly estimated at ~ 10^{14} atom cm^{-2} s^{-1} on some assumptions. As the deposition time increases, plasma driven permeation (PDP) rate decreases. The PDP rate is four times less than the initial one at ~ 200 s. Meanwhile, H_2 gas driven permeation (GDP) rate stays almost the same.

From fig. 1, it is considered that the carbon deposition does not influence the GDP rate. The deposited carbon layer is presumed to be porous, hence hydrogen molecule can easily pass through the deposited carbon layer and reach the membrane surface active in dissociative uptake for hydrogen molecule. On the other hand, the carbon layer is considered to be impervious to suprathermal hydrogen particles. It is inferred that the deposited carbon is active in chemically binding with suprathermal hydrogen particles, therefore hydrogen atom and ions are trapped by the carbon layer. Assuming that the PDP rate is proportional to reciprocal width of the carbon layer, the fitting line is also drawn in fig. 1, normalizing L at initial state ($L = L_0$). The agreement with the experimental results is good during the whole range.

Fig. 2 shows temperature dependence of the carbon deposition effect on the PDP rate. Amount of the deposited carbon was ~ 10^{15} atoms. The ratio J/J_0, J_0 is the PDP rate before carbon deposition and J is the PDP rate after carbon deposition respectively, depends on the membrane temperature T_M. At $T_M \geq 1073$ K, the J/J_0 becomes ~1, namely deterioration of the PDP by the carbon deposition is almost disappearing. From auger electron spectrometry results, this may be attributed to dissolution of the deposited carbon into the bulk of the membrane.

In order to apply the membrane pump to the fusion devices, it is necessary to estimate the carbon deposition rate in the fusion devices. If the carbon deposition rate is smaller than that of this experiment, it is expected that the carbon deposition effect will reduce and the membrane pump can operate at lower membrane temperature.

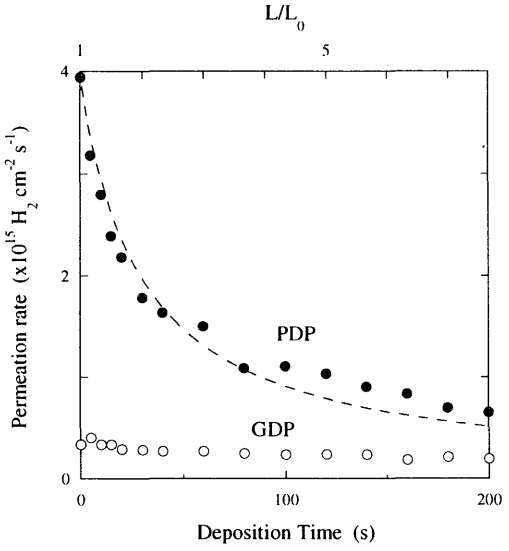

Fig. 1. Dependence of GDP rate and PDP rate on carbon deposition time.

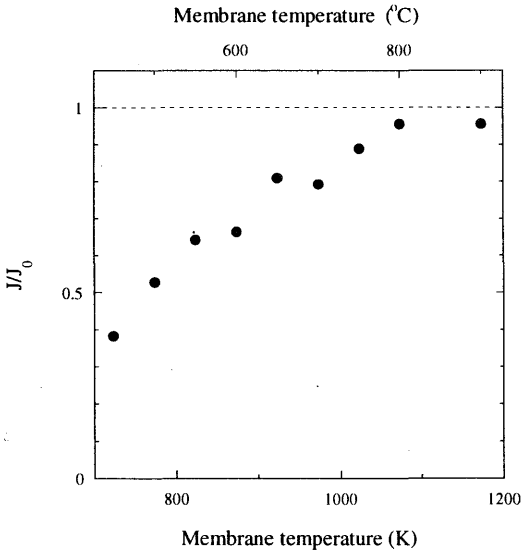

Fig. 2. Dependence of carbon deposition effect on membrane temperature.

Reference

1) Nakamura, Y. et al.: Ann. Rep. NIFS (1997-1998) 44.