§2. Hydrogen pumping performance of a niobium panel for LHD

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The hydrogen release rate of a niobium panel for LHD was investigated for considering the influence of the temperature and the amount of absorbed hydrogen on the hydrogen pumping performance. The release rate from a metal surface j_r ($cm^{-2}\ s^{-1}$) is expressed in an equation

$$j_r = k_r c_0^2, \quad (1)$$

k_r ($cm^4\ s^{-1}$) and c_0 (cm^{-3}) stand for a recombination coefficient and a hydrogen concentration at the surface.

In order to measure the time evolution of the hydrogen release, the panel absorbing ~ 10 Pa m^3 of H_2 was heated at various temperatures. The experiment was carried with a device especially made for investigating the characteristics of the panel.[1] The panel and the experimental procedures have already described in detail.[2] Hydrogen diffusivity in the panel is so fast enough that hydrogen concentration in the panel is assumed to be uniform. On the condition, c_0 is calculated with an equation $c_0 = C/V$, C and V are the amount of absorbed hydrogen and the volume of the panel. Dependence of k_r on the panel temperature T_p (K) derived from the time evolution is shown in Fig. 1. ln k_r is considered to be directly proportional to the reciprocal of T_p. The approximate line is expressed in an equation

$$k_r = 2.51\times10^{-17} \exp\left(-\frac{2\times0.60(\mathrm{eV})}{k_B T_p}\right). \quad (2)$$

Dependence of the pumping performance of the panel on the temperature and the amount of absorbed hydrogen is calculated with k_r expressed in eq. (2). Net hydrogen pumping rate of the panel s ($cm^{-2}\ s^{-1}$) is the difference between the absorption rate j_{ab} ($cm^{-2}\ s^{-1}$) and j_r. s is expressed in an equation

$$\begin{aligned} s &= j_{ab} - \left(j_{r\,up} + j_{r\,down}\right) \\ &= j_{ab} - \left(k_{r\,up} c_{0\,up}^2 + k_{r\,down} c_{0\,down}^2\right), \end{aligned} \quad (3)$$

the index "up" indicates a surface on which atomic hydrogen impinges and the index "down" indicates the other side surface. Supposing that $k_{r\,up} \sim k_{r\,down}$ and $c_{0\,up} \sim c_{0\,down}$, eq. (3) can be simplified

$$\begin{aligned} s &\simeq j_{ab} - 2k_r c_0^2 \\ &= j_{ab} - 2k_r C^2/V^2. \end{aligned} \quad (4)$$

Dependence of s/j_{ab} on C calculated on a condition $j_{ab} = 10^{16}\ cm^{-2}\ s^{-1}$ in the cases of T_p = 500, 600 and 700 K is shown in Fig. 2. s/j_{ab} is expressed the influence of hydrogen release on s. If the release rate is small enough compare to j_{ab}, s/j_{ab} remains unity and hydrogen release from the panel has little effect on the pumping performance. The dotted line expresses the expected daily amount of hydrogen impinged on the panel during the LHD experiment. On the line, more than 90 % of the absorbed hydrogen is pumped by the panel even in the case of T_P = 700 K.

In conclusion, hydrogen release from the panel is considered not to cause serious deterioration of the pumping performance during the LHD experiment if the temperature keeps < 700 K.

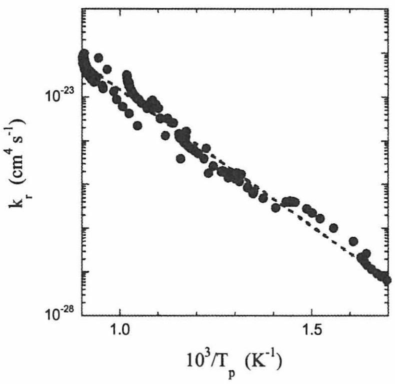

Fig. 1. Dependence of the recombination coefficient k_r on the panel temperature T_p.

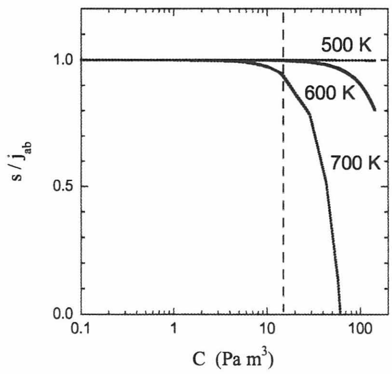

Fig. 2. Dependence of the pumping performance of the panel s/j_{ab} on the temperature and the amount of absorbed hydrogen C.

Reference
1) Nakahara, Y. et al. : Ann. Rep. NIFS (1999-2000) 90.
2) Nakahara, Y. et al. : Ann. Rep. NIFS (2000-2001) 87.