

§21. Kinetics of Hydrogen Isotopes at Surfaces and Bulks of Plasma Facing Materials Based on Group 5 Metals

Hatano, Y., Hara, M. (Univ. Toyama), Hashizume, K. (Kyushu Univ.), Saitoh, H. (Muroran Inst. Tech.), Suzuki, A. (Univ. Tokyo), Ashikawa, N., Nagasaka, T., Sagara, A., Muroga, T., Nakamura, Y.

Group 5 metals including V are candidate materials of superpermeable membranes for pumping fuel particles in a divertor region. In addition, V alloys have attractive mechanical and nuclear properties as structural materials of fusion blankets. From these viewpoints, the interactions of hydrogen isotopes including tritium with V and V alloy were investigated by different experimental techniques.

Durability of V membrane under expected conditions in vacuum vessels of fusion reactors was examined and compared with that of Nb and Ta. The suppression of recombinative release of incident hydrogen isotopes by non-metallic impurity (e.g. oxygen) is indispensable to achieve superpermeation regime. The removal of such surface impurity by sputtering is a critical issue. This type of problem can be solved by doping the bulk of membranes with oxygen through continuous surface segregation of oxygen. Fig. 1 shows the correlation between oxygen concentrations in the bulk, C_O , and surface recombination rate constant of hydrogen, k_r , for V, Nb and Ta¹⁾. For all metals, k_r decreased with increasing C_O . These observations clearly indicate that oxygen is effective to suppress the reemission of hydrogen isotopes. Although the effect of oxygen observed for V was smaller than that for Nb and Ta, superpermeation through V membrane was maintained due to continuous surface segregation of oxygen under the irradiation of 250 eV hydrogen ions at incident flux of $1 \times 10^{20} \text{ m}^{-2} \cdot \text{s}^{-1}$ and membrane temperature at/below 773 K. In addition, the value of k_r on V surface was much more stable than that on Nb. For example, no significant change in k_r was observed for V during the sputtering for 25 ks under the above-mentioned conditions, while the irradiation of hydrogen ions to Nb under comparable conditions led to increase of k_r by 10 times.

Surface modification by deposition of impurities in plasma is also important issue. Indeed, the deposition of carbon and formation of carbide layer were observed for Nb panel examined in LHD. Nevertheless, it was found that carbide layers formed on V, Nb and Ta are permeable for hydrogen. Hence, the deposition of carbon could not be a problem if the membranes are operated at sufficiently high temperatures where deposited carbon is converted into carbides. Since diffusivities of carbon in V and its carbides are higher than those in Nb, Ta and corresponding carbides, the highest conversion rate from deposited carbon into carbides is expected for V. Superpermeable membranes made of V appeared to be more reliable than those of Nb and Ta under various conditions.

For the application as structural materials of blankets, the diffusion of tritium in the bulk and the

influence of temperature gradient on it are also important. From these viewpoints, the diffusion coefficient of tritium, D_T , and the heat of transport, Q_T^* , in a V-4Cr-4Ti alloy (NIFS-HEAT-2) were measured.

Fig. 2 shows the Arrhenius plot of D_T in the V-4Cr-4Ti alloy together with that in pure V. The values of D_T in the alloy were significantly smaller than those in pure V. The activation energy for the diffusion in the alloy was higher in the low temperature region. These observations indicate that at least two types of trapping sites are present in the alloy. One type of the trapping sites was assigned to Ti dissolved in the alloy matrix, and trapping energy was evaluated to be 0.08 eV. Observation of tritium distribution by imaging plate technique indicated that precipitates consisting of Ti and interstitial impurities (C, N and O) also act as trapping site for tritium.

The heat of transport Q_T^* in the alloy was evaluated to be $21 \text{ kJ} \cdot \text{mol}^{-1}$ at 333 K, indicating that tritium should be concentrated in low temperature area. The obtained value of Q^* is significantly larger than that in pure V (ca. $8 \text{ kJ} \cdot \text{mol}^{-1}$)²⁾. In other words, the distribution of tritium in V-4Cr-4Ti alloy is much more sensitive to temperature gradient than that in pure V.

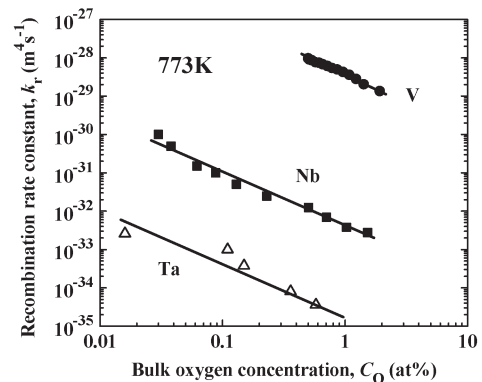


Fig. 1 Correlation between oxygen concentrations in bulk and surface recombination rate constant of hydrogen for V, Nb and Ta¹⁾.

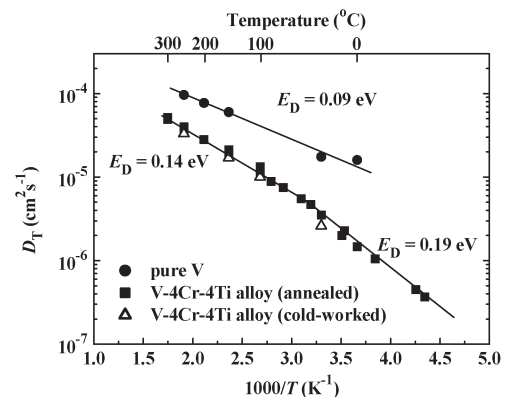


Fig. 2 Diffusion coefficient of tritium in V-4Cr-4Ti alloy.

- 1) A. Busnyuk and A. Livshits, private communication
- 2) M. Sugisaki, K. Hashizume and K. Fujii, J. Alloys & Compounds, **253-254**,(1997) 401