§93. Effects of Microstructure and Additional Elements of Tungsten on Bulk Diffusion and Retention of Hydrogen Isotopes

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To improve tungsten materials embrittlement, control of microstructure, alloying, and grain boundary enforcement by dispersoids addition and fine graining. In some cases, these improvements increase trapping sites of tungsten. In the other cases, they affect diffusion of hydrogen isotopes into the bulk. In consideration of importance of neutron damage, which produces hydrogen isotope trapping sites in the bulk of tungsten, the effects of these modification for improving embrittlement of tungsten on retention should be known well and must be reflected to new tungsten materials development.

In this study, three types of W materials were used; powder metallurgy and hot rolled tungsten (grain orientation parallel to the surface), and TFGR (Toughened Fine Grained Recrystallized) tungsten with TaC dispersoids. These materials were exposed to a mixture gas of D and T (7.2%) at a pressure of 8.9 Torr at temperatures of 573 K, 673 K and 773 K. After gas exposure, T retention and depth profile were measured by an etching method.

Figure 1 shows the depth profiles of pure W (rolling direction parallel to the surface) at the exposure temperatures of 673 K and 773 K, and TFGR-W at the exposure temperature of 673 K. For pure W cases, a high concentration peak was found near the surface but decreased to the level of between 10^{-7} and 10^{-8}. For TFGR-W, a profile is similar to those of pure W at 673 K, but saturation level is slightly higher because of more intrinsic defects due to fine grains and dispersoids. One of the problem of this experiment was difficulty for etching of TaC dispersoids. As shown in Fig. 1, depth profile of TFGR-W was shown only up to the depth of about 40 μm. This is because TaC remained near the surface and eventually etching stopped due to this surface accumulation of TaC. This means tritium trapped at TaC might not be etched and remained. Therefore, the concentration in TFGR-W could be underestimated.

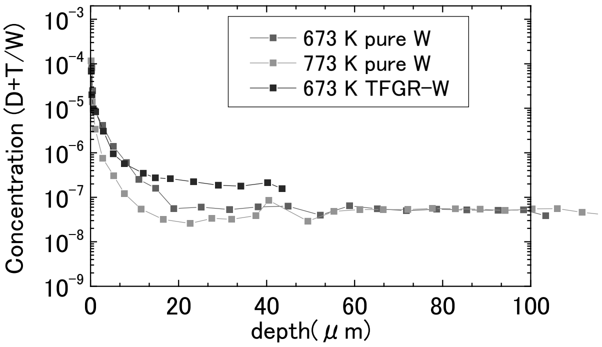

Fig. 1 Depth profiles of pure W at 673 K and 773 K, and TFGR-W (TaC) at 673 K

In order to understand D and T diffusion into the bulk and their trapping behavior simple calculation using the model proposed by Oriani [1]. This model is based of diffusion of hydrogen isotopes with trapping and detraining as an annihilation term and a source term, respectively. The calculation profiles together with experimental results are shown in Fig. 2. In this calculation, a diffusion coefficient of Frauenfelder was assumed [3].

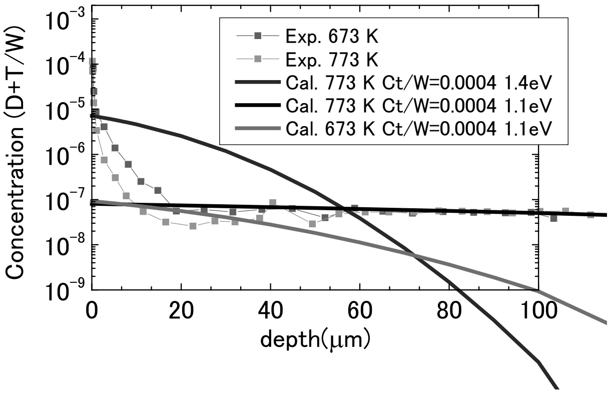

Fig. 2 Depth profiles of hydrogen isotopes (experiments and calculation using the Oriani model). Two trapping energies were assumed as 1.4 eV and 1.1 eV. Trapping site density of 4 x 10^{-4} was assumed based on the experiments [2].

It was found that calculated profile showed relatively good agreement with experimental one at 773 K, C_t/W of 4 x 10^{-4} and the trapping energy of 1.1 eV (similar to vacancy trapping energy). But in the case of higher trapping energy (1.4 eV) or lower temperature (673 K), calculation results did not agree with experimental results.

So far, although it is not difficult to draw some conclusion, at least two experimental data showed that tritium diffused into the bulk and fill the traps (with the equilibrium concentration) up to 100 μm. We will make more experiments to understand trapping and diffusion mechanisms in the bluk.

[1] R. Oriani, Acta Metall. (1970).
[2] M. Oya, et al., presented at 21st PSI in Kanazawa (2014).
[3] R. Frauenfelder, J. Vac. Sci. Technol. 6, 388 (1969).