§28. Retention Dynamics in Damaged Tungsten

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Recent studies show neutron damaged sites in tungsten can trap significant tritium in the bulk. Detailed studies of damage characteristics, local concentration, dependence of dpa, and difference between ion damage and neutron damage are under progress. Since neutron damaged sites are created in the bulk of tungsten, their tritium retention could reach unacceptable amounts even in DEMO reactors. One of the removal methods proposed is isotope exchange with non-active hydrogen isotopes (H or D) with T. But its mechanisms are not very clear yet. This exchange reactions take place at relatively low temperatures and recently from first principle calculations this could be related to multiple trapping of one defects[1] (vacancy and so on). To make more detailed studies and clarify isotope exchange mechanisms, it is necessary to make systematic experiments by varying irradiation conditions and temperature conditions.

In this study, we make systematic scan of temperature conditions to compare experimental data and simulation data to understand isotope exchange mechanism at damaged sites of tungsten. Ion damage was made by 6.4 MeV Fe ions at 473 K. Then H and D ions with the energy of 1 keV at 473 K were injected sequentially to observe hydrogen isotope exchange between H &D. Residual H and D in tungsten was measured by TDS.

Figure 1 shows newly fabricated sample holders to precisely control specimen temperature.

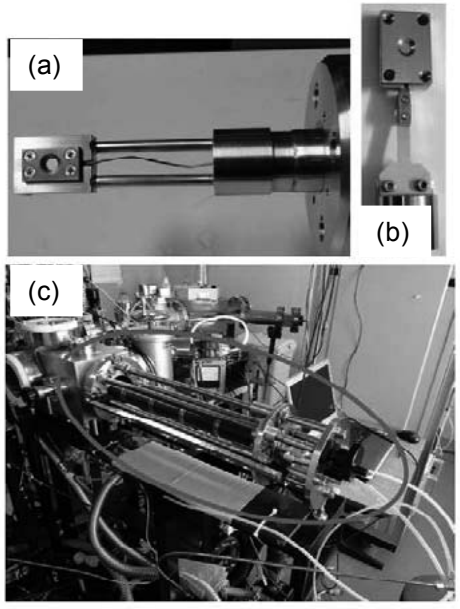

Fig. 1 New sample holders. (a) low temperatures (<500 K) and (b) high temperatures (up to about 1000 K). (c) Linear drive mechanism of the holders.

Figure 2 and 3 show how H& D retentions evolve with post irradiation fluence. In Fig. 2, H was pre-irradiated and D was post-irradiated, in Fig. 3 vice versa. Pre-irradiation fluences of H or D (1.5 x 10^{24} m^{-2}) were enough to fill all the ion damaged traps.

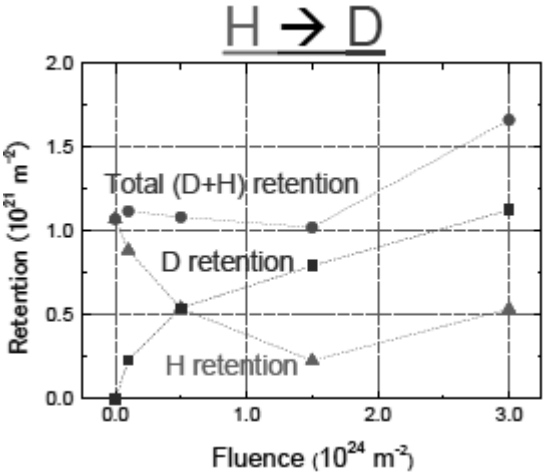

Fig. 2 Evolution of retention as a function of post fluence. Pre-irradiation species is H and post-irradiation species is D at 473 K.

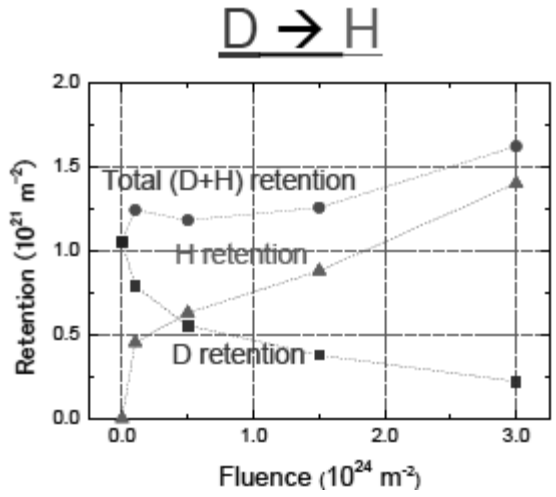

Fig. 3 Evolution of retention as a function of post fluence. Pre-irradiation species is D and post-irradiation species is H at 473 K.

After post-irradiation of 0.5 x 10^{24} m^{-2} (1/3 of pre-irradiation fluence), roughly half of initially trapped hydrogen isotope was exchanged. To see TDS data in detail, hydrogen isotope released at relatively low temperatures (around 550 K) was firstly exchanged, suggesting hydrogen isotope with relatively low binding energies was exchanged first. But as the post-fluence increases, those at high energy trap sites were also exchanged. Then at the same post- and pre-irradiation fluences, about 75 % of pre-retained components were exchanged. As the fluence increases more, total retention increased, which could be due to newly trapping sites creation by post-ion implantation. It is interesting to note that no notable isotope effects were observed, namely similar exchange efficiencies for H to D and D to H.

[1] K. Ohsawa et al., PHYSICAL REVIEW B **82**, 184117 (2010).