§24. 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 isotope exchange behavior Fe damaged tungsten (0.7 dpa at a peak position of damage profile). For (a), D was implanted followed by H implantation, and for (b) vice versa. Under current experimental conditions with relatively high ion energy of 1 keV and high fluence of an order of 10^{24} m^{-2} D(H) ion implantation itself could dominate trap sites formation probably due to oversaturation effects. Therefore, TDS data shown in Fig. 1 could closely relate to isotope exchange phenomena at these self-created sites.

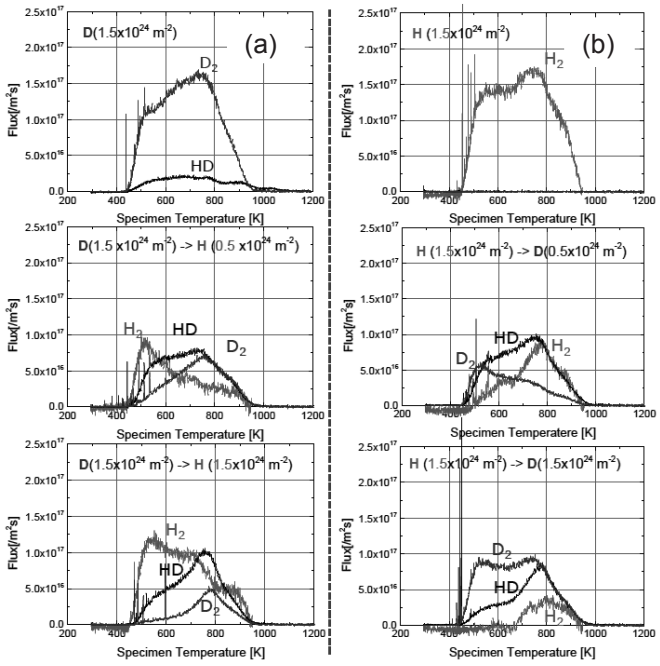

Fig. 1 TDS profile data for isotope exchange from D (H) to H (D). (a) D implantation to 1.5x10^{24} m^{-2} followed by H implantation to 0.5 x 10^{24} and 1.5 x 10^{24} m^{-2}. (b) Exchange implantation order of D and H. H implantation first.

From Fig. 1 (a), as post H implantation fluence increased isotope exchange from D to H proceeded. At first, H desorption in the TDS spectrum is dominant at low temperatures, then desorption around high temperatures was increased up to 950 K, where desorption of all hydrogen isotopes stopped. Since low temperature desorption corresponds to that from low energy trapping sites, isotope exchange firstly took place at weak trapping sites and developed to strong trapping sites. Even at the trappings sites from which D is not released around ion irradiation temperature of 473 K, isotope exchange took place.

Then we changed an order of D and H implantation. Improvement in vacuum quality raised S/N ratio of H signal to an acceptable level for TDS measurements. It was found

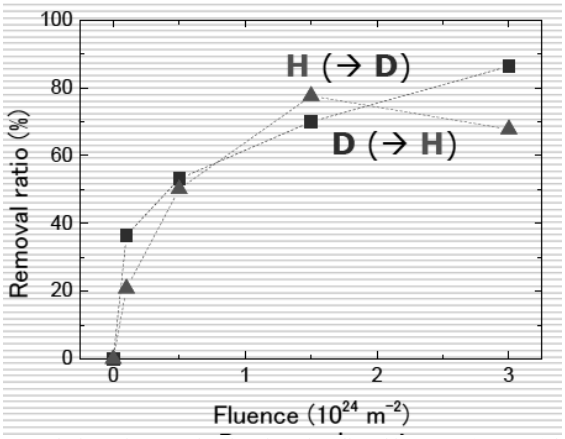

Fig. 2 Evolution of removal ratio of pre-irradiated isotopes (D or H) by post -irradiation of the other isotopes (H or D).

that similar behavior of isotope exchange took place for the H to D case. For the case (b) (H to D), isotope exchange also started at low temperatures and as post fluence (D) increased isotope exchange at high temperatures proceeded.

In Fig. 2, removal ratio of pre-irradiated isotopes by post-irradiated isotopes. It was found that the removable ratio increased sharply till about 0.5 x 10^{24} m^{-2} and almost saturated over 1.5 x 10^{24} m^{-2}. Quite similar behavior was seen for two different order irradiation cases. These results suggest that there are very few isotopes effects for the isotope exchange reactions at hydrogen trapping sites created by oversaturation phenomena and high energy ion damage (6.4 MeV Fe).

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