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イオン照射損傷を与えたタングステン中の水素同位体交換
Hydrogen isotope exchange in ion-damaged tungsten

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1. Introduction

Tungsten is one candidate for plasma facing materials (PFMs) in ITER and is planned for future fusion reactors. PFMs are simultaneously exposed to fuel particles and 14MeV neutrons generated by DT reactions. The radiation damage produced by the neutrons will increase tritium retention in tungsten (W) due to production of hydrogen isotope trap sites [1]. Increased tritium retention will impact safety and operational limits of ITER and future fusion reactors. Therefore, it is important to assess the trap characteristics produced in tungsten and develop the way to remove tritium trapped in these sites. It is known that annealing is one way to remove tritium. In this study, however, we study the effect of isotope exchange because it could take place at lower temperatures than annealing temperatures.

2. Experimental

Two types of hydrogen isotope exchange experiments with 700keV ion-damaged W were carried out. Firstly, ion-damaged specimens irradiated by deuterium (D) are irradiated by hydrogen (H) at 473 K (Type-1 experiment). The fluences were 1.5×10^{24} D/m^2 and 1.0×10^{23} to 1.5×10^{24} H/m^2. Secondly, similar damaged specimens irradiated by D at 473 K were annealed at 573 K to desorb D at relatively low energy trap sites (~1.4 eV) [2] before H irradiation at 473 K (Type-2 experiment). The purpose is to investigate the effect of the isotope exchange against the strongly trapped D (~2.0 eV) [2]. D depth profile was observed up to 1.5 μm by D(^{3}He,p)^{4}He nuclear reaction by using a Van de Graaff generator in Kyoto University. The energy of ^{3}He was 1.7 MeV.

3. Results

Type-1 experiment showed that more than 76% of trapped D up to the depth of 1.5 μm was removed by H irradiation (Fig. 1). The release rate of D atoms was the highest in near surface region (within 0-0.5 μm). In this region, reduction in D retention took place instantaneously after H irradiation, which indicates mobile H atoms diffused to this region within the fluence of 10^{23} H/m^2. The D retention near the surface (0-0.5 μm) was reduced by two orders of magnitude in the H fluence of 1.5×10^{24} H/m^2 (corresponding to 1.5×10^4 sec). Therefore, isotope exchange is very effective to remove T atoms trapped in this depth region. At deeper regions, reduction in D retention also took place, but is slower than that of top surface region.

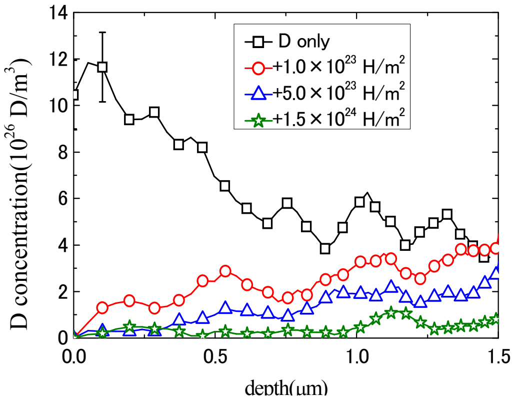

Fig. 1 D depth profile after H irradiation (Type-1 experiment) 1.5×10^{24} D/m^2 + 0~1.5×10^{24} H/m^2

Type-2 experiment also showed H fluence dependence for removal efficiency of strongly trapped D. For 1.0×10^{23} H/m^2 irradiation, the amount of retained D was not clearly decreased at all regions. For the fluences of 5.0×10^{23} H/m^2 and 1.5×10^{24} H/m^2, the amount of trapped D atoms was reduced up to the depth of 1.0 μm. For the fluence of 1.5×10^{24} H/m^2, about 66% of initial D was desorbed up to the depth of 1.5 μm. From these experiments, our data showed the removal efficiency sharply decreases with depth, which suggests that isotope exchange would not be useful within a reasonable time for the removal of T accumulated at neutron induced trap sites in deep regions. This is a remaining issue for the T removal by the isotope exchange process.

References

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