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様々な温度にて炭素照射したタングステンにおける欠陥形成と重水素滞留挙動の相関関係に関する研究

Study of correlation between defect formation and retention behavior of deuterium in carbon-implanted tungsten at various carbon implantation temperatures

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The usage of tungsten has been considered as the plasma facing material (PFM) in D-T fusion reactors. The PFM is exposed to energetic hydrogen isotopes and impurities like carbon during plasma operation. It is considered that the irradiation defects will be introduced by these energetic particles on the tungsten surface, resulting in the increase of hydrogen isotope retention in the PFM. Therefore, elucidation of a correlation between hydrogen isotope retention behaviors and formation of irradiation defects is quite important to understand the fuel recycling in the PFM during the operation. In addition, the first wall is exposed to high heat load in the D-T fusion reactors. Therefore, it was also necessary to understand effects of carbon implantation temperature on the formation of irradiation defects and the hydrogen isotope retention. In this study, C^+ pre-implantations into tungsten at various C^+ implantation temperatures were performed. Thereafter, D_2^+ implantation was carried out at room temperature to clarify the temperature dependence on defect formation and deuterium retention for carbon implanted-tungsten. TDS (Thermal desorption spectroscopy) measurements were performed to investigate the deuterium retention behavior in tungsten. TEM (Transmission Electron Microscopy) observations were also performed to observe the irradiation defects formed by the ion implantations.

A disk-type polycrystalline tungsten (10 mm^{ϕ}×0.5 mm^{t}) purchased from Allied Material Co. Ltd was used. The sample was preheated at 1173 K for 30 minutes under ultrahigh vacuum (>10^{-6} Pa) to remove the impurities and damages introduced during the polishing processes. The C^+ pre-implantation was done with the energy of 10 keV C^+ and the ion fluence of 1.0×10^{21} C^+ m^{-2} at room temperature, 473 K or 673 K. For the D_2^+ implantation, 3.0 keV D_2^+ implantation was performed for C^+ pre-implanted tungsten with the ion fluence of 1.0×10^{22} D^+ m^{-2} at room temperature. After the ion implantation, TDS measurements were performed from room temperature to 1173 K with a heating rate of 0.5 K s^{-1} to investigate the deuterium retention behavior. The TEM observations were also performed to observed the irradiation defects formed by the ion implantations.

Figure shows the D_2 TDS spectra for the tungsten sample implanted with C^+ as a function of C^+ implantation temperature. There were two deuterium desorption stages at around 400 K and 550 K, attributing to the desorption of deuterium trapped by dislocation loops and trapped by vacancies, respectively. The retention of deuterium trapped by vacancies was increased as the C^+ implantation temperature increased. For TEM observation, however, the amount of dislocation loops was almost the same among these C^+ implanted samples even if the implantation temperature was changed, indicating that the amount of vacancies was almost the same among these samples. On the other hand, the voids were clearly formed for the C^+ implanted sample at 673 K, indicating that the increase of the amount of deuterium desorbed at around 550 K was caused by the deuterium trapped by the voids. It was considered that the aggregation of vacancy was induced by the enhancement of irradiation induced diffusion of vacancies due to the higher C^+ implantation temperature. Therefore, it was indicated that the increase of C^+ implantation temperature will enhance the hydrogen isotope retention in tungsten due to the formation of voids. However, the desorption temperature of deuterium shifted toward lower temperature region compared to that in only D_2^+ implanted tungsten in our previous study. This difference will be discussed in the presentation.

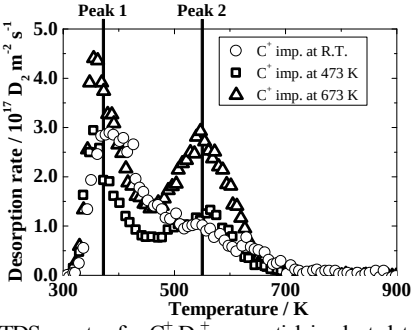

Fig. D_2 TDS spectra for C^+-D_2^+ sequential implanted tungsten with various C^+ implantation temperatures and only D_2^+ implanted tungsten