§31. Effects of Simultaneous Helium Irradiation on Hydrogen Behavior in Plasma Facing Materials

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In fusion reactors, tungsten is a leading candidate for plasma facing materials (PFMs) due to high melting point, low sputtering yield by light ions, and high thermal conductivity. Its brittleness by hydrogen isotope and helium ions, however, is one of the serious concerns. To study this subject in detail, it is important to know hydrogen and helium behavior in tungsten. In fact, quite a few studies have been done on hydrogen or helium behavior in tungsten by mono-species ion irradiation to tungsten. In actual fusion devices, however, hydrogen isotopes (D and T) and helium ions (5~10%) simultaneously impinge on plasma facing materials. Therefore, it is important to study synergistic effects of hydrogen and helium to correctly evaluate tungsten materials response in fusion reactors.

In our laboratory in Osaka University, from 1996 to 2001, new steady state high flux ion beam irradiation test devices, called HiFIT, was constructed by LHD collaboration study with NIFS. Last year we showed that the small addition (0.1%) of helium suppressed blister formation of tungsten. This indicated that helium ion implantation reduces hydrogen influx into the bulk of tungsten. It is known that implanted helium tends to agglomerate at vacancies to form helium bubbles, which could cause internal stress and reduce diffusion. Studies on this issue, however, have been very few, though this effect would be important for hydrogen isotope behavior in first walls.

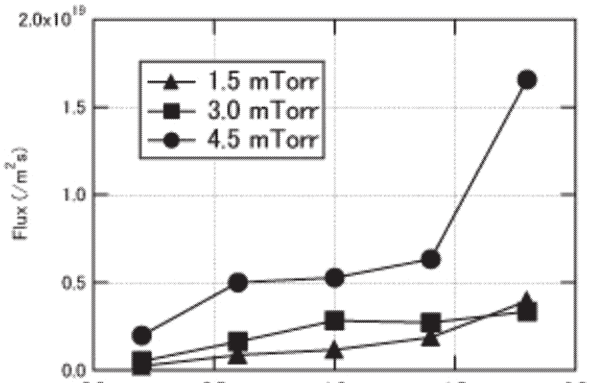

Fig. 1 He flux 15 cm away from the He ion source. This flux consists of ion and neutral. Neutral helium was produced by a charge exchange reaction between helium ions and ambient helium gas.

To study the detailed mechanism and make useful database, we planned to install a new helium ion beam source, which enabled us to irradiation samples with H and He ion beam with different energies. The helium flux with this ion beam at 15 cm from it is shown in Fig. 1. In this source, we replaced an ion extraction grid with the fewer extraction holes so that the helium gas flowing out from the source was reduced. He flux obtained by this grid were between 10^{18} and 10^{19} $m^{-2}s^{-1}$. Ion fluxes from the main beam source was an order of 10^{20} $m^{-2}s^{-1}$. Therefore, roughly 1% of He flux compared with that of the main source can be injected to the samples. Since only 0.1% of helium can suppress blistering, this helium flux is enough to study the helium effects on hydrogen isotope. Mixed ion beam experiments with two separate ion sources will be made in the next year.

Helium and hydrogen mixed irradiation effect was also studies for ultra-fine-grained (UFG) tungsten, developed by H. Kurishita[1]. This tungsten has many advantages for plasma facing materials such as little or no radiation (neutron, He) hardening, superplasticity, and high tolerance for repetitive heat pulse. However there is a concern about hydrogen and helium trapping due to large grain boundary area. So we made hydrogen and helium irradiation experiments for UFG-W.

Figure 2 shows the results. In this case, we use 1 keV hydrogen ion beam (H_3^+ is a main component) with ~0.8%:C, which has been used for many types of tungsten samples and most of them showed blisters at the temperature of 65for many types of tungsten samples and most of them showed blisters at the temperature of 653K.

It is clearly shown that UFG-W does not show hydrogen blistering (a). Only shows some pits, which could be produced by grain ejection. By adding 0.1 He to this beam, the number of small pits were reduced, which is similar to pure W cases. But some pits still remained. We need to know this grain ejection will have an impact on erosion enhancement. This is the important issue for the use of UFG-W as plasma facing materials.

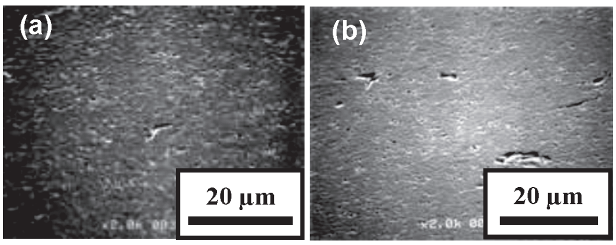

Fig. 2 Surface morphologies of UFG-W irradiated with 1keV H_3^+ with 0.8%:C (a), and 1 keV H_3^+ with 0.8%:C and 0.1%:He(b).

References
[1] Y. Ishijima et al., Materials Transactions, 46, 568(2005).
[2] Y. Ueda et al., J. Nucl. Mater. 337-339 (2005) 1010.