§34. 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 study 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%) 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. One of the result of mixed ion irradiation with hydrogen and helium by using HiFIT is shown in Fig.1. Without helium ions in the beam (hydrogen with slight carbon addition (~0.8%)), dome-shape blisters clearly appeared on the tungsten sample. Addition of only 0.12% He to hydrogen and carbon mixed ion beam, however, completely suppressed blistering. It is known that He atoms in tungsten form He bubbles, which do not disappear even over 1500 K. These He bubbles could affect hydrogen retention and diffusion in tungsten, leading to suppression of blistering.

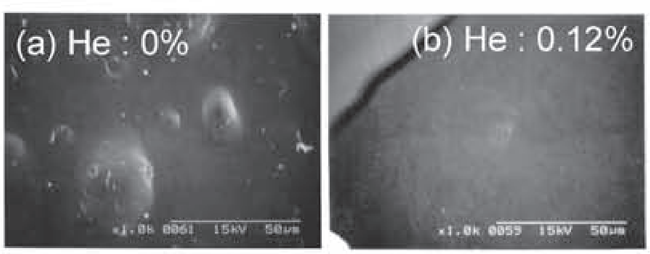

Fig. 1 Blistering due to hydrogen and carbon mixed ion beam irradiation (1 keV H_3^+ as main component, C concentration ~0.8%). Sample temperature is 653 K. Sample is sintered tungsten plate with hot rolled process with stress relieved annealing process.

From this result, it is clear that He effects must be taken into consideration to understand hydrogen isotope behavior in tungsten. In previous study with HiFIT, hydrogen ions and helium ions were extracted from one ion source, which means relative energies of hydrogen and helium cannot be changed. In actual fusion devices, helium ions exist in edge plasmas as doubly charged ions and impinging energy of helium is approximately twice as large as hydrogen isotopes. If helium energy becomes higher than hydrogen isotope ions, the helium ion range is larger and the location of helium bubble formation becomes deeper. This fact could affect helium effects on hydrogen behavior in tungsten. In our present HiFIT system cannot cope with this situation.

In present framework in LHD collaboration study, in order to study this complicated hydrogen and helium irradiation condition to plasma facing materials new mixed ion beam irradiation device has been constructed based on HiFIT. The schematics of the new device is shown in Fig. 2. New helium ion source with helium energy from 0.2 keV to 2 keV will be installed to HiFIT to make independently controlled hydrogen and helium mixed ion irradiation experiments to plasma facing materials. Helium ion species ratio in hydrogen dominant ion beam can reach as high as about 10%, which can cover actual fusion edge plasma conditions.

In the first year of this collaboration study (2005), new helium ion beam source was purchased and we confirmed that this ion source worked properly with helium working gas. In the next year, we will install this helium ion source to HiFIT to complete the preparation for mixed ion beam irradiation study.

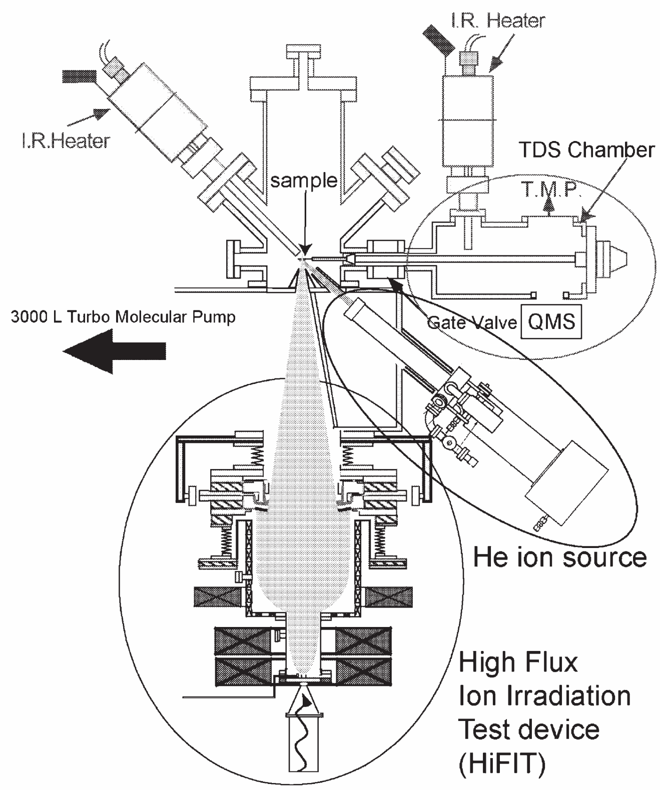

Fig. 2 New H and He ion beam irradiation device