Rapid Communications

Blister Formation on Tungsten Surface by Irradiating Hydrogen and Carbon Mixed Ion Beam

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A mixed carbon and hydrogen beam was irradiated on to tungsten materials. In the case in which the carbon concentration and sample temperature were 0.95% and 653 K, respectively, large numbers and blisters of various sizes were formed. But in a low carbon concentration or high temperature case, no significant blisters were formed. It was found that carbon impurities in the beam play an important role in blister formation.

Keywords: PFM, mixed ion beam, tungsten, carbon impurity, blistering

Next-step fusion reactors will use various kinds of materials for PFM. For example, in the case of the International Thermo-nuclear Experimental Reactor (ITER), Be will be used for the first walls and C and W for the PFM of the divertors [1]. It is of concern that the simultaneous use of these materials will lead to mixed-layer formation on all surfaces, which would affect not only surface erosion physically or chemically, but also cause surface deformations such as blister formation. So far, studies regarding pure hydrogen or its isotope ion irradiation into tungsten have been performed at beam energies of 100 ~ 1,000 eV and temperatures of 300 ~ 500 K [2–5]. These studies showed that blisters (at sizes of up to 50 μm) form due to hydrogen diffusion beyond the ion range and then being trapped at vacancies, dislocations, and voids. But only a few data regarding the effects of impurities on blister formation and hydrogen retention are available [6,7] and intensive studies focusing on this issue are necessary in order to correctly evaluate tungsten performance as PFM. This study was performed to investigate the effects of impurities on blister formation by carbon and hydrogen mixed beam irradiation to tungsten material.

The experiment was performed in the High Flux Ion Test device (HiFIT) (Fig.1) [8,9]. All results were obtained using sintered tungsten samples ($10 \times 20 \times 0.5$ mm^t, mirror polished, Nilaco Co.). A sample was positioned at the focal point of the beam in the irradiation chamber. To limit the area of irradiation, a 3 mm diameter aperture was set in front of the samples. Beam energy, flux, and fluence were 1.0 keV, ~ 4.0×10^{20} $\mathrm{m}^{-2}\mathrm{s}^{-1}$, and 10^{24} ~ 10^{25} m^{-2}, respectively. Sample temperature was measured using thermocouples. Samples were heated to 653 K ~ 873 K by means of an IR-heater. Before and after beam irradiation was applied to the sample materials, the beam mass spectrum was measured in order to estimate the beam species and carbon concentration. Figure 2 shows the typical mass spectrum of the mixed ion beam. In this beam, hydrogen ions were extracted mainly as H_3^+ (70 ~ 80

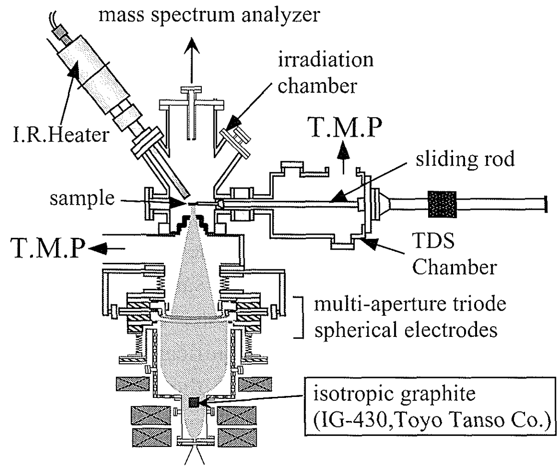

Fig.1 Schematic view of steady state and High Flux Ion beam Test device (HiFIT)

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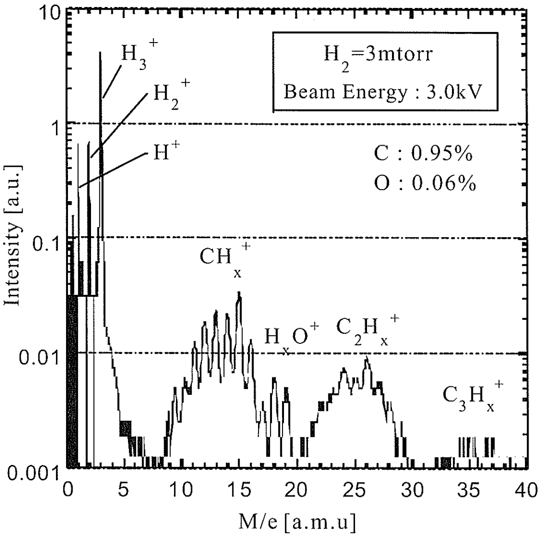

Fig.2 Ion mass spectrum of mixed ion beam. Hydrogen gas pressure is 3 mtorr and beam energy is 3.0 kV.

%), and carbon flux was about 0.95%. The carbon concentration in the beam can be controlled by changing the amount of graphite plates put inside the ion source and the flow rate of the puffed methane gas.

In the case in which the beam energy, carbon concentration and sample temperature were 1.0 keV, 0.95%, and 653 K, respectively, a large number and various sizes of blisters (up to around 1.0 mm) were formed with the fluence of 7 × 10^{24} m^{-2} (Fig.3 (a)). The irradiated area was eroded by about 200 nm. In the case of a low carbon concentration of 0.11% (the other beam parameters were the same as those of 0.95% case), no significant blisters were formed on the sample (Fig.3 (b)). The two following reasons might explain such a large blister formation. One is that implanted carbon diffuses beyond the ion range and creates defects to trap hydrogen atoms and molecules. The other is that a tungsten carbide layer (more than 100 nm by XPS measurement) enhances hydrogen diffusion beyond the ion range and tungsten carbide layer. As the sample temperature was raised, the number of blister decreased. At a temperature of 873 K, no significant blisters were formed. At higher temperatures, the traps would not be active because hydrogen could have enough thermal energy to escape the trap site. Hydrogen could quickly diffuse through the material, lowering retention and thus limiting blister formation.

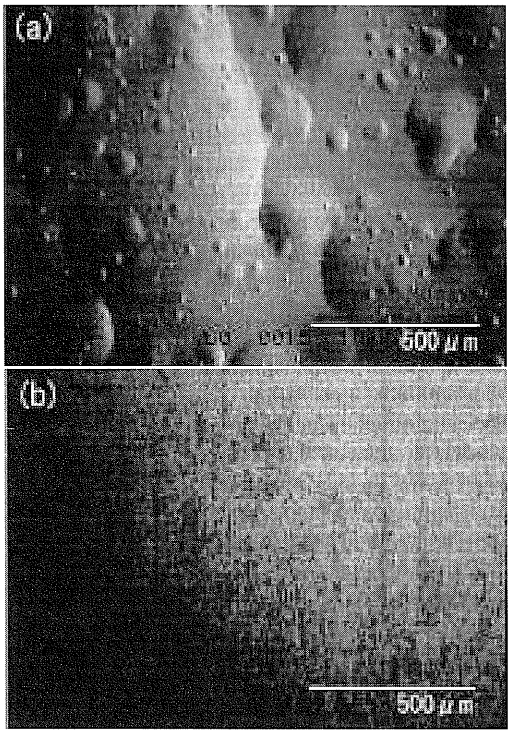

Fig.3 SEM photograph of the tungsten target after irradiated by ion beam. Carbon concentration is (a) 0.95%, (b) 0.11%

It is concluded that a very small amount of carbon impurity in the hydrogen beam plays a very important role in large blister formation. It is very important to take account the effects of carbon impurities when evaluating the blister formation, and to determine the amount of hydrogen retained in tungsten if tungsten is adopted with carbon as PFM.

[1] G. Federici *et al*, J. Nucl. Mater. **290-293**,260(2001).
[2] A. Haasz *et al*, J. Nucl. Mater. **266-269** ,520 (1999).
[3] Wenmin Wang *et al*, J. Nucl. Mater. **299**,124 (2001).
[4] T. Venhaus *et al*, J. Nucl. Mater. **290-293**,505 (2001).
[5] R. A. Causey *et al*, J. Nucl. Mater. **300** ,91 (2002).
[6] M. Poon *et al*, J. Nucl. Mater. **283-287** ,1062 (2000).
[7] V. Kh. Alimov *et al*, J. Nucl. Mater. **282** ,125 (2000).
[8] T. Shimada *et al*, J. Plasma Fusion Res. Series **3**, 312 (2000).
[9] T. Shimada *et al*, *to be published in* Rev. Sci. Instrum.