§ 8. Retention Characteristics of Boron Thin Films under High Flux Ion Irraditation

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In LHD experiments, boron coating method is used for impurity control, mainly oxygen. Hydrogen ions or helium ions are implanted and retained in boron thin films during discharges. This hydrogen or helium retention could affect particle balance of core plasma. Therefore, it is important to understand retention characteristics of boron films under LHD edge plasma conditions.

In this work, retention characteristics of boron thin films produced by vacuum deposition or ion plating technique are studied by the high flux ion beam test device (HiFIT). The HiFIT device is equipped with an ECR ion source with triode spherical electrodes, which focuses broad ion beam onto the target materials to obtain high ion flux up to about 3 x 10^{21} H/m^2 for 3 keV H_3^+. The details of this device was described elsewhere[1]. In this work, boron thin films were irradiated by 0.5 keV H_3^+ ion beam at normal incidence with fluence of 2.0 x 10^{24} H/m^2. Carbon impurity concentration in the beams was controlled by putting graphite plates in the ion source chamber to supply carbon atoms as hydrocarbon molecules produced by chemical sputtering. Oxygen impurity concentration was always about 0.05 %, which was independent of carbon concentration. The other impurity concentration was less than a detection limit (~ 0.01 %). Irradiation temperature was about 80°C. Elevation speed of sample temperature for TDS was 1K/s.

Boron thin films were made by vacuum evaporation with a conventional 270° deflection type EB gun (4kV, 500 mA). The substrate were Mo plates with the dimensions of 9.5 x 50 x 0.4 mm. Substrate temperature was carefully controlled within 3°C. Film thickness was measured by a thickness monitor with a quartz crystal oscillator. In addition, the film thickness was measured afterwards in air by a surface profilometer to make a precise calibration.

Figure 1 shows TDS of hydrogen for the cases of carbon concentration for 0.08 % (a), 0.25%(b), and 1.0% (c) with the fluence of about 2 x 10^{24} H/m^2. It was found that TDS curves consist of mainly three peaks. The peak temperatures are about 550 K (Peak 1), 670 K (Peak 2), and 800 K (Peak 3). The height of peak 1 increased with carbon concentration in ion beams, which indicates that Peak 3 was formed by desorbed hydrogen once trapped by carbon atoms in boron films. On the other hand, the height of Peak 1 and Peak 2 decreased with carbon concentration in ion beams. These two peaks could be formed by desorbed hydrogen which was trapped by boron atoms.

According to surface profilometer measurements, ion-irradiated boron surface was eroded by about 100 nm for C:0.25% (b), while deposition by about 200 nm was observed for C:1.0% (c). Surface atom composition of irradiated samples was measured by XPS. In the case of C:0.25% (b), top surface was covered by the mixture of boron, carbon and oxygen. Whilst in the case of C:1.0% (c), top surface was completely covered by carbon.

From the balance equation between carbon deposition and carbon erosion[2], when carbon concentration in the beam exceeds about 0.6%, carbon tends to accumulate over boron substrate. This resul agrees well with experimental results. This threshold concentration increases with the decrease in erosion rate of substrate. For example, in the case of tungsten substrate, The threshold concentration increases to about 1.5%.

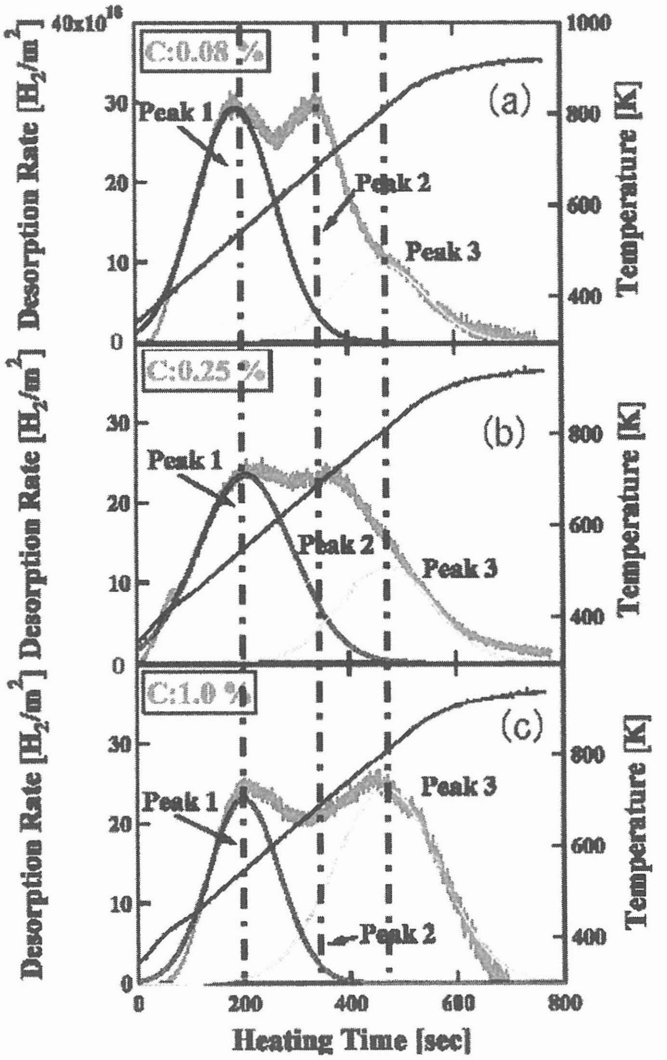

Fig.1 TDS spectra from boron thin films irradiated by 1 keV H_3^+ ion beam. Carbon concentration is 0.08 % for (a), 0.25 % for (b), and 1.0 % for (c). Expermental data are fitted with the sum of three Gaussians (Peak 1, Peak 2, and Peak 3).

References
1) T. Shimada, et al., Rev. Sci. Instrum. 73 (2002) 1741.
2) K. Krieger, J. Roth, J. Nucl. Mater. 290-293 (2001) 107.