§4. Retention Characteristics of Boron Thin Films under High Flux Ion Irradiation

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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 3×10^{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. 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. The highest TDS temperature was limited to about 900 K due to exfoliation of boron films from Mo substrates.

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 0.1 % with fluence as a parameter. It is known that TDS spectra of H from boron containing carbon impurity consist of mainly three peaks at 550, 670 K, and 800 K. The peaks at 550 K and 670 K would be formed by hydrogen atoms combined with boron atoms. The peak at 800 K would be related with carbon, though the reported TDS peak temperature from pure graphite is somewhat higher (around 1000-1100 K). In our experiments, these main desorption peaks from pure graphite could not be observed due to the limit of the substrate temperature. From Fig. 1, the desorption peak at 800 K was not pronounced for C:0.1%. Main hydrogen desorption took place at 550 K and 670 K. In this case, boron surface was under sputtering erosion condition with mainly hydrogen ions and carbon deposition on boron films did not influence hydrogen retention in boron films much.

On the other hand in Fig. 2 for C:1.0-1.2%, the desorption peak at 800 K became much more pronounced. In this case carbon atoms deposited on boron films to control hydrogen retention. Hydrogen desorption from boron layer increased until the fluence of 4.6×10^{24} H/m^2 were reached. As the fluence increased more, the boron layer were mostly covered by the carbon layer and hydrogen desorption from the boron layer decreased at the fluence of 7.3×10^{24} H/m^2. In this high fluence case, main hydrogen desorption peaks could be higher than our TDS temperature range (up to 900 K). Therefore, it is difficult to estimate hydrogen retention accurately.

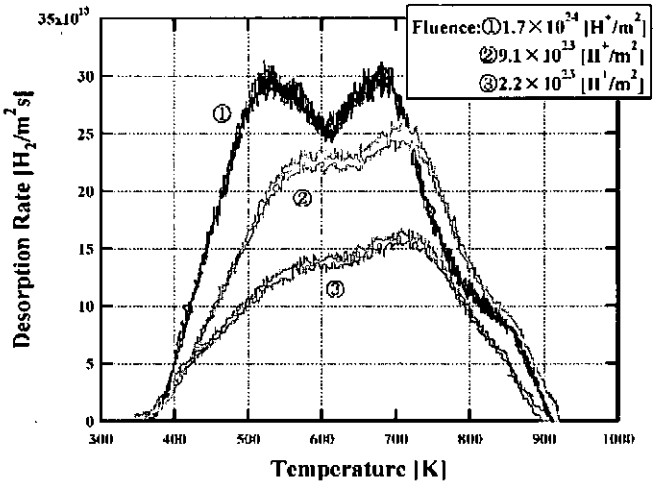

Fig. 1 TDS spectra for C:0.1%.

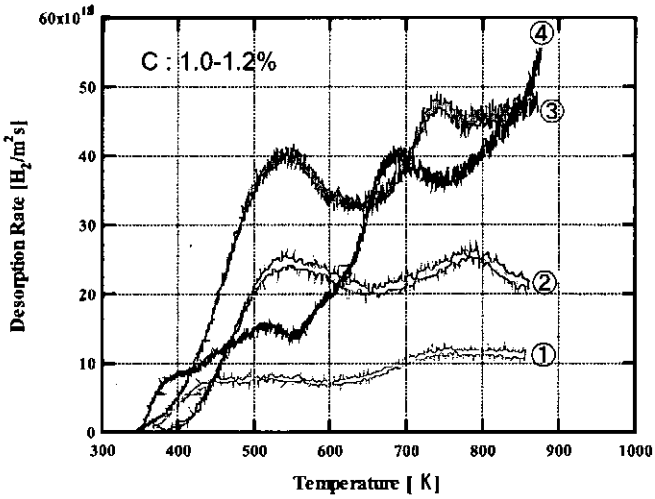

Fig.2 TDS spectra for C:1.0-1.2%. Irradiation fluences are 9.4×10^{21} H/m^2 ①, 2.2×10^{24} H/m^2 ②, 4.6×10^{24} H/m^2 ③, 7.3×10^{24} H/m^2 ④.

References
1) T. Shimada, et al., Rev. Sci. Instrum. 73 (2002) 1741.
2) Y. Yamauchi, et al., J. Nucl. Mater. 220-222 (1995) 851.