§10. 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 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 1 keV H_3^+ ion beam at normal incidence with fluence of 1.3 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.

During thin film formation, internal stress was measured from the change in curvature induced in the substrate by using an optically levered laser method. The light source was a He-Ne laser with a power of 1.5 mW. The laser beam was focused on the detector by the cylindrical les with 1000 mm focal length. The resulting translation of the reflected beam was measured by a position sensitive detector (PSD, Hamamatsu S3931) with a sensitive area of 1 x 6 mm^2. As deposition rate was increased, tensile stress in the boron thin films increased, which suggested that the interatomic distance of the boron films increased with the deposition rate. This result agreed with the results of radial distribution function of boron thin films measured by TEM[2]. The tensile stress for the samples in this experiment is about 1 GPa.

Figure 1 shows TDS spectra for the cases of carbon concentration of 0.4 % (a) and 0.05%(b). For the low carbon concentration case (b), desorption peak was observed around 200°C and 350 °C and most of hydrogen was desorbed below the temperature of about 400°C. On the other hand, for the high carbon concentration case (a), new desorption peak appeared around 500°C, in addition to the peak observed in the low C case.

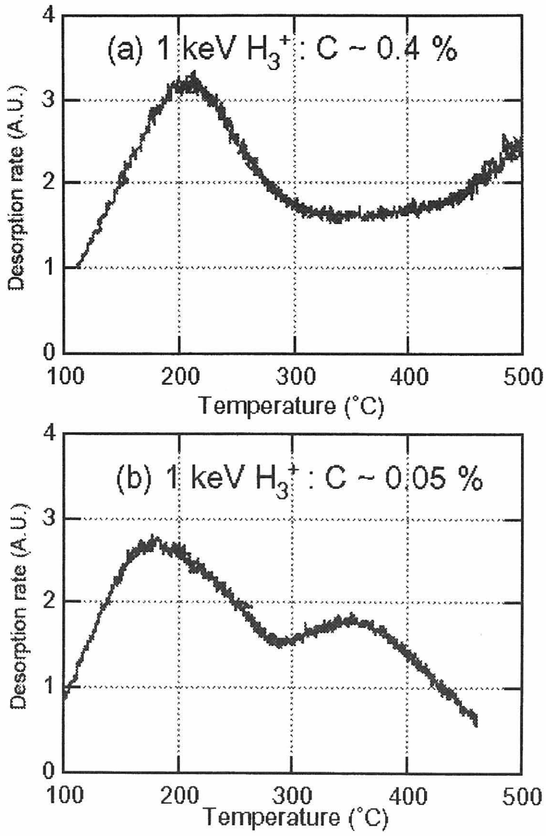

Fig.1 TDS spectra from boron thin films irradiated by 1 keV H_3^+ ion beam. Carbon concentration is 0.4 % for (a) and 0.05 % for (b).

In the previous works done by Hino et al.[3] and Tsuzuki et al.[4], hydrogen desorption behavior from boron thin films formed by glow discharge using diborane or decaborane gas showed the highest peak around 350°C and two other small peaks around 200°C and 500°C. The peak positions of our experimental result are similar to these results, though the highest peak appeared around 200°C in our experiment. Since the desorption peak around 500°C appeared for the high C concentration case, this peak could be related to carbon impurity.

In the future, the dependence on fluence, C concentration, irradiation angle, and formation condition of boron thin films will be investigated.

References
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