§30. Study on Impurities Effects and Hydrogen Isotopes Retention Behavior in Impurities-contained Boron Films

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i) Introduction

For steady state operations of D-T plasma in fusion devices, it is important to keep impurities low in plasma. In the Large Helical Device (LHD) of the National Institute for Fusion Science (NIFS), boronization has been applied as a first wall conditioning technique. Boron easily traps the impurities such as oxygen and carbon existing in vacuum vessels. In boronization, boron is deposited on the first wall with the impurities and it is expected that energetic hydrogen isotopes including tritium escaping from D-T plasma will be implanted into the boron film contained with the impurities. Tritium is thought to be trapped not only by boron but also by the impurities in the boron film. Therefore, the interactions between the energetic hydrogen isotopes and the boron film contained with the impurities should be elucidated for evaluation of tritium inventory in fusion reactors.

In the present study, the boron film (LHD-boron) was prepared on Si substrates by boronization at LHD. After boronization, the samples were exposed to H-H discharge at LHD, or deuterium ion (D_2^+) implantation at Shizuoka University.

ii) Experimental

The boron films, namely pure boron film (Sample 1) and carbon (Sample 2), oxygen (Sample 3) and carbon-oxygen (Sample 4) contained boron films were prepared by means of Plasma-assisted Chemical Vapor Deposition (P-CVD) apparatus at Shizuoka University. Before preparation, only helium gas was purged at the flow rate of 3.8 sccm and plasma discharge was performed to clean up the chamber. After cleaning, the plasma discharge with sample source gases was performed to prepare all the samples on the Si substrate. After boronization, Samples 1, 2 and 3 were exposed to 147 shots of H-H discharge in LHD. Sample 4 was heated at 1173 K for 10 min to remove residual hydrogen. Thereafter, 1.0 keV D_2^+ was implanted into the sample with ion flux of 1.0×10^{18} D^+ m^{-2} s^{-1} up to the ion fluence of 1.0×10^{22} D^+ m^{-2} at room temperature. The XPS measurement was carried out to evaluate the chemical state of boron films with H-H discharge or D_2^+ implantation. The TDS analysis was also performed from room temperature to 1173 K with the heating rate of 0.5 K s^{-1}.

iii) Results and discussion

From the XPS result, atomic composition ratios of boron, carbon and oxygen in Sample 1 were 33%, 28% and 39%, respectively. These results were almost the same as that in Samples 2 and 3, indicating that the atomic concentration of impurities should be governed by the particle fluxes of impurities from H-H plasma. The chemical states of implanted carbon and oxygen by H-H plasma discharge were free carbon and free oxygen, respectively.

The figure shows the H_2 TDS spectra for Samples 1, 2 and 3 after exposure to H-H discharge and D_2 TDS spectrum for Sample 4 after D_2^+ implantation. The TDS spectrum consisted of three stages, located at around 500, 750 and 900 K. From the previous study, these stages were attributed to the desorption of H trapped as B-H-B, B-H, B-O/C-H bonds, respectively[1]. The retentions of hydrogen as B-O-H and B-C-H bonds were not observed for Samples 1, 2 and 3. In contrast, most of deuterium in Sample 4 was trapped by impurities as B-O-D and B-C-D bonds. In Samples 1, 2 and 3, the major chemical states of oxygen and carbon were free oxygen and free carbon, respectively. Therefore, hydrogen implanted by H-H discharge was trapped by boron as B-H-B, B-H bonds, or quickly desorbed as H_2O and CH_x. In Sample 4, most of deuterium was trapped by O-B and/or C-B bonds to form B-O-D and B-C-H bonds. These results indicate that the tritium retention is influenced by chemical states of oxygen and carbon in boron film.

It can be said that the clarification of chemical states of oxygen and carbon implanted by D-T plasma was impotant for the evaluation of tritium inventory in fusion reactors.

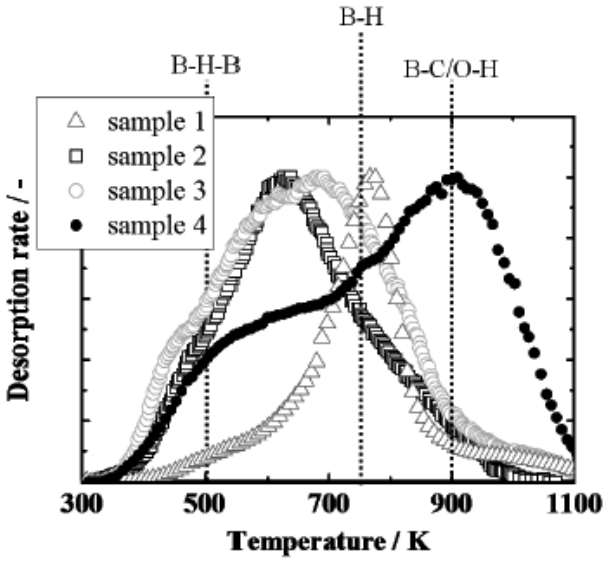

Fig. The H_2 /D_2 TDS spectra for all samples

1) A. Yoshikawa, *et al., J. Nucl. Mater.*, **367** (2007) 1527.