§37. 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 the impurities low in plasma. In the Large Helical Device (LHD) of National Institute for Fusion Science (NIFS), boronization has been applied as a first wall conditioning technique. Boron easily bounds to 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 escaped from D-T plasma will implant into the boron film contained with impurities. Tritium is thought to be trapped not only by boron but also by impurities in the boron film. Therefore, for the evaluation of tritium inventory in fusion reactor, the interactions between the energetic hydrogen isotopes and the boron film contained with impurities should be elucidated.

In the present study, the LHD-boron was prepared on Si substrate by boronization at LHD. After boronization, the samples were exposed to H-H discharge at LHD, or deuterium ion (D_2^+) implantation. The behaviors of deuterium retention and chemical states of boron, oxygen and carbon in the LHD boron films were investigated by means of Thermal Desorption Spectroscopy (TDS) and X-ray Photoelectron spectroscopy (XPS), respectively.

ii) Experimental

The LHD-boron was prepared on a Si substrate by boronization in LHD. The Si substrates were firstly exposed to He glow discharge to remove the impurities adsorbed on the surface. Boronization was performed by the glow discharge at 300 K for about 7 hours and the thickness of the boron film was estimated to be around 1 μm by the combination usage of XPS and Ar^+ sputtering techniques. The diborane (B_2H_6) and He gases were used as material and dilute gases, respectively.

After boronization, the LHD-boron film was exposed to 67 shots (total 150 sec) of H-H discharge in LHD. On the other hand, the other LHD boron film was implanted by deuterium ions (D_2^+) at Shizuoka Univ. The D_2^+ implantation was performed at room temperature with the ion energy of 1.0 keV and the flux of 1.0×10^{18} D^+ m^{-2} s^{-1} up to the fluence of 1.0×10^{22} D^+ m^{-2}. After H-H discharge or D_2^+ implantation, XPS measurement was carried out to evaluate the chemical state of LHD 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

The D_2 TDS spectrum for the D_2^+ implanted LHD boron film consisted of four stages, located at around 500, 700, 850 and 950 K. From the previous study, these stages were attributed to the desorption of D trapped as B-D-B, B-D, B-O-D and B-C-D bonds, respectively [1]. The results of XPS spectra indicated that oxygen existed as O-B bond and free oxygen, and carbon also existed as C-B bond and free carbon in the LHD boron film. In addition, it was found that the carbon decreased to 80% while oxygen decreased to 60% in the LHD boron film by D_2^+ implantation. The deuterium retention decreased to 30% in LHD boron for D_2^+ implantation compared with the pure boron film for D_2^+ implantation. From these results, it was found that deuterium retention of LHD boron film decreased for D_2^+ implantation compared with the pure boron film, indicating that the D_2^+ would selectively sputter free oxygen and free carbon in the boron film and formed D_2O and CD_X. Therefore, during D_2^+ implantation, some of deuterium would be released as D_2O and CD_X.

Figure shows the ratio of hydrogen isotope retention for each desorption stage in LHD boron films after H-H plasma exposure and D_2^+ implantation. It was found that most of hydrogen isotope in the D_2^+ implanted LHD boron was retained as B-D bond, however, that for H-H discharge was trapped as B-O-H and B-C-H bonds.

In the LHD boron film, hydrogen isotope implanted by H-H discharge would be released as water and hydrocarbons, whereas be trapped by impurities with forming B-O-X and B-C-X bonds, Since the impurities effects would have a large impact on chemical behavior of boron film, these effects should be considerd in plasma operation.

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

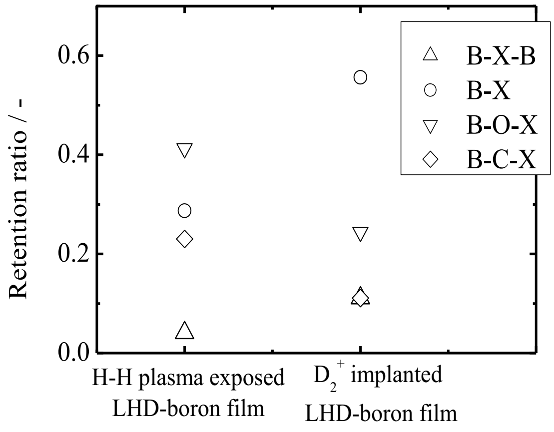

Fig. The ratio of hydrogen isotope retention for each desorption stage after H-H plasma exposed and D_2^+ implanted LHD boron films.