# § 6. Dynamics of Hydrogen Isotopes in a Boron Coating Membrane

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i) Introduction

In LHD, since the baking temperature for vacuum vessel is limited to be below 100 °C, the alternative method for improve plasma performance is required. Boronization, which is one of the attractive wall conditioning method to reduce impurities, such as oxygen, carbon, and iron, is considered as one of key issues to achieve high plasma performance [1]. Boron coating by boronization is subject to high-flux implantation of low-energy hydrogen isotope atoms and ions that would be escaped form magnetic confinement during D-D and/or D-T fusion operation. From the viewpoint of safety for D-D and/or D-T fusion reactors, dynamics of hydrogen isotopes, such as tritium inventory, trapping states, and desorption behaviors implanted into a boron coating must be required to elucidate. In this study, dynamics of hydrogen isotopes implanted into two types of boron coating membranes prepared with using $B_{10}H_{14}$ and $B_2H_6$, were investigated by means of X-ray photoelectron spectroscopy (XPS), Thermal desorption spectroscopy (TDS), and β-ray-induced X-ray spectrometry (BIXS).

ii) Experimental

The boron coatings were conducted by PCVD with $B_{10}H_{14}$ diluted with helium using a PCVD apparatus fabricated at Shizuoka University. The prepared coatings were characterized by XPS. Two kinds of experiments were performed as follows.

First, tritium ions were implanted into two types of a boron coating prepared with $B_{10}H_{14}$ and $B_2H_6$. After implantation, residual tritium in the boron coatings was measured by BIXS at the temperature region from room temperature to 500 °C.

In the second experiment, the 1.0 keV deuterium ion was implanted into two types of a boron coating with different atomic composition and boron polycrystal up to the fluence of $1.0 \times 10^{22}$ D $m^{-2}$. Each sample was heated up to 1350 K with a heating rate of 0.5 K $s^{-1}$ in a newly designed TDS apparatus.

iii) Results and discussion

Two types of boron coatings, B/SS316($B_2H_6$)-1 and B/SS316($B_{10}H_{14}$)-10, were analyzed by XPS and the results were as follows; two boron coatings consisted of B, C, N and O, and the atomic composition of boron (B/(B + C + N + O)) in each sample was 0.78 and 0.48, respectively. The results of residual tritium in the boron coating after tritium implantation were shown in Fig. 1. When the samples were heated up to 450 °C, the ratio of desorption amount to the initial retention of tritium for B/SS316($B_2H_6$)-1 was 1.4 times less than that for B/SS316($B_{10}H_{14}$)-10. This may be due to difference in impurity level in the coatings. Furthermore, no diffusion behavior of tritium into SS316 appeared during an isochronal heating process.

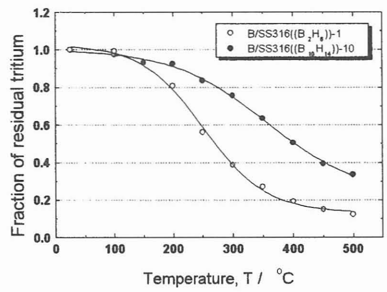


Fig. 1. Desorption behavior at an isochronal heating process.

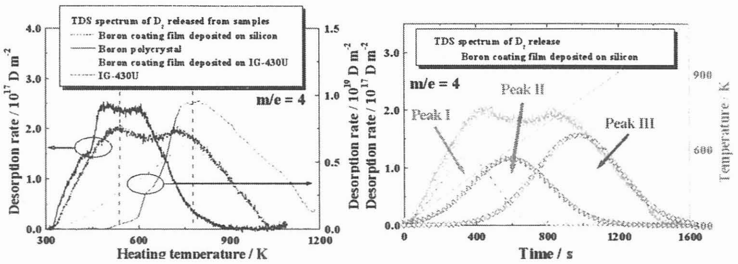


Fig. 2. (a) TDS spectra of each sample after $D_2^+$ ion implantation and (b) the analyzed TDS spectra of $D_2$ released from boron coating film deposited on silicon.

Figure 2(a) shows TDS spectrum of $D_2$ released from each sample after $D_2^+$ implantation [2]. There were two major deuterium release stage observed at around 500 and 750 K, which correspond to the desorption of deuterium trapped by boron and carbon, respectively. The amount of deuterium release stage around 750 K was increased as increasing the amount of carbon impurity. In the TDS spectrum for boron coating deposited on silicon, the TDS spectrum was divided into three peaks (PeakI,II and III) using Gaussian distribution function as shown in Fig.2(b). It was found that the peaks I and II correspond to the desorption of deuterium trapped by boron. It can be said that the hydrogen isotopes were trapped in boron with two different chemical states. In addition, there is no chemical shift observed by XPS after deuterium ion implantation. These results indicate that hydrogen isotope would be trapped by the interstitial sites in a boron coating. To investigate the dynamics of hydrogen isotope in detail, further research will be required.

iv) Conclusion

To investigate the dynamics of hydrogen isotope in a boron coating, boron coatings were prepared using the newly designed PCVD apparatus at Shizuoka University. It was found that the impurity in the boron coating make an important role for the hydrogen isotope retention. Hydrogen isotopes were trapped with two different chemical states in the boron coatings.

References

[1] A. Sagara, et al. : NIFS Annual Report., 11 (1992).
[2] H. Kodama et al.,: J. Nucl. Mater., 313-316 (2003) 155.