§17. Dynamics of Hydrogen Isotopes in Boron Coating Membrane

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i) Introduction

Boronization for wall conditions has been developed to reduce impurities in vessel, such as oxygen, carbon, and high-Z elements, in particular iron. It has led to remarkable improvements for operational performance in fusion devices. The boron coating membrane 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-T fusion operation. From the viewpoint of safety for D-T fusion reactors, tritium inventory, trapping states, and desorption behaviors of tritium implanted into boron membrane have been required to elucidate. In this study, the chemical states of deuterium implanted into boron coating membrane were investigated by means of XPS and TDS.

ii) Experimental

The boron thin membrane was prepared by PCVD with decaborane ($B_{10}H_{14}$) diluted helium using plasma processing teststand apparatus in NIFS [1]. The prepared samples on IG-430U were characterized by XPS. Deuterium ion implantation into the boron coating membrane was carried out with 1.0 keV D_2^+ and then the XPS measurement for the sample was repeated until the deuterium ion fluence reached to 1.0×10^{22} D m^{-2}. In the TDS experiments, the samples were heated up to 1350 K with a heating rate of 0.5 K s^{-1} after the D_2^+ implantation with 1.0 keV D_2^+ and 1.0×10^{22} D m^{-2}.

iii) Results and discussion

Characterization of the boron coating membrane by XPS showed that the membrane consisted of B, C, N and O. The atomic composition ratios of boron (B/(B + C + N + O)) and carbon were 0.43 and 0.47 on surface, and 0.62 and 0.23 in bulk, respectively. Oxygen and nitrogen existed uniformly within the boron coating membrane from surface to bulk. It was found that the major atomic components were B and C.

From the XPS results, the peak top energy of B-1s shifted to high-energy-side and then became almost constant in the region of more than 5.0×10^{21} D m^{-2}. The chemical shift of C-1s indicated same as that of B-1s. The chemical shifts to high energy side resulted from the valence electrons around B and C atoms being attracted to the deuterium atoms due to stronger electronegativity of D than those of B and C. These results indicated that the deuterium implanted into the boron coating membrane could be interacted with B and C chemically, which formed B-D and C-D bonds.

Figure 1 shows TDS spectrum of D_2 released from boron coating membrane after D_2^+ implantation. It was found that the desorption of D_2 consisted of two processes indicated peak 1 and 2 shown in Fig.1. This result implied that two

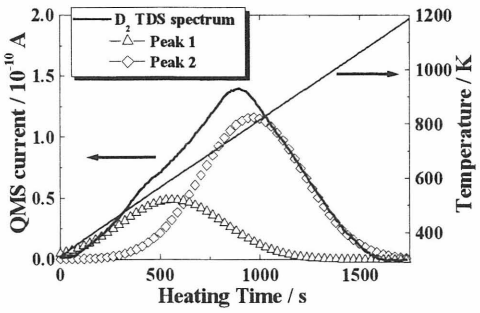

Fig. 1 The analyzed TDS spectrum of D_2 released from boron coating membrane after D_2^+

trapping sites existed in the boron coating membrane. The TDS spectrum obtained from the boron coating membrane in this study was similar to that on boron-carbon films after D^+ implantation [2]. The release of D_2 from boron-carbon films at lower and higher temperature was attributed to the detrapping from B-D and C-D bond, respectively. Taking into account of this result, it was suggested that peak 1 and 2 in this TDS experiment was contributed to detrapping of deutrium from B-D and C-D bonds in boron coating membrane, respectively. Therefore, it was suggested that the implanted deuterium was trapped by forming the B-D and C-D bond. This is consistent with that for the XPS experiments.

Figure 1 also suggests that there could be possibility of reduction of tritium inventory by using boronization to wall condition because the deuterium trapped by B-D bond was released at lower temperature than that for C-D bond. To confirm this suggestion, the more investigations of chemical behaviors for implanted deuterium should be required. Therefore, the PCVD apparatus to prepare the boron thin membrane and the system to measure XPS for prepared sample without exposing air has been commissioned at Radiochemical Research Laboratory of Shizuoka University.

iv) Conclusion

The chemical states of deuterium implanted into boron coating membrane were investigated by means of XPS and TDS.

Characterization of the boron coating membrane showed that the atomic composition of the sample was B, C, N, and O. It was found that a majority of the atomic composition was B and C. In the XPS experiments, it was found that the chemical states of deuterium implanted into boron coating membrane was namely B-D and C-D bonds from results of chemical shifts on B-1s and C-1s. This result was supported with the result of the TDS experiments.

References

[1] Natsir, M., et al. : J. Nucl. Mater., 220-222 (1995) 865.
[2] Yamaki, T., et al : J. Nucl. Mater., 217 (1994) 154.