§10. Study on Oxygen and Carbon Impurities Synergy Effects on Tritium Retention Behavior in Boron Films in LHD

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i) Introduction

For deuterium plasma experiment in LHD, it is important to estimate the retention behavior of hydrogen isotopes, including tritium, in boron film produced by boronization from the viewpoint of tritium inventory control.

In previous studies, it was clarified that the hydrogen isotope retention behavior in carbon-oxygen containing boron film deposited onto silicon substrate can be estimated by the chemical state of impurities. Recently, tungsten is a primary candidate material for plasma facing materials in fusion reactor. For applying the data of the hydrogen isotope retention behavior in boron film prepared on silicon substrate to that on tungsten, the effect of substrate on the hydrogen isotope retention behaviors should be elucidated. In this study, boron films deposited on silicon and tungsten substrates in LHD were exposed to hydrogen plasma in LHD. The hydrogen retention behaviors in these boron films were elucidated by measurement of the hydrogen retentions in these boron films and the chemical states of these boron films.

ii) Experimental

Boron films prepared by the boronization in LHD on silicon and tungsten substrate were used. These samples were preheated at 973 K for 10 minutes to remove the residual hydrogen retained during boronization processes. These samples were placed at the 4.5-low port of the LHD and exposed to 179 shots of hydrogen plasma. The chemical states of boron and impurities were evaluated by means of X-ray Photoelectron Spectroscopy (XPS). The hydrogen retention behavior in boron films was studied by Thermal Desorption Spectroscopy (TDS) with the heating rate of 0.5 K s^{-1} up to the temperature of 1173 K.

iii) Results and discussion

The H_2 TDS spectra for hydrogen-plasma-exposed samples consisted of three desorption stages at 500, 700 and 800 K as shown in the figure. These desorption stages were attributed to the desorption of hydrogen trapped as B-H-B bond, B-H bond and B-O-H or B-C-H bonds, respectively. Total hydrogen retentions in boron film on silicon and tungsten were 2.0×10^{20} H m^{-2} and 1.4×10^{20} H m^{-2}, respectively. The retention of hydrogen trapped by boron (B-H-B, B-H) in the boron film on tungsten was decreased compared to that on silicon, considering that the chemical states of boron films were different among these boron films.

The chemical states of these boron films after hydrogen plasma exposure were almost the same from the results of XPS. However, the chemical states of these samples before hydrogen plasma exposure were different. The C-B, C-C and C-O bonds were formed in these samples and the amount of carbon was not changed by hydrogen plasma exposure. However, the ratio of C-B bond in boron film on tungsten was higher than that on silicon. The O-O bond was major chemical state for oxygen. The amount of oxygen in the boron film on tungsten was larger than that on silicon. In previous study, deuterium retention as B-C-H bond is controlled by the amount of C-B bonds. Thus, it was indicated that the amount of hydrogen trapped as B-C-H bond was increased by increase of C-B bond in boron film on tungsten compared to that on silicon. In addition, the O-O bonds would induce chemical sputtering of hydrogen, promoting the release of water during hydrogen plasma exposure. Therefore, the reduction of hydrogen retention trapped by boron (B-H-B, B-H) in the boron film on tungsten was proceeded.

It can be concluded that the clarification of the chemical states of boron films before and after plasma operation were necessary to estimate the hydrogen retention in boron films under the actual reactor environment. Therefore, the estimation of the chemical state change of boron film by plasma exposure is required in fusion reactor.

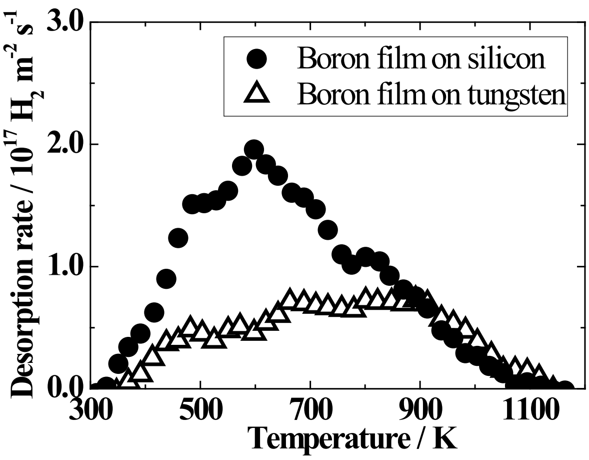

Fig. The H_2 TDS spectra for hydrogen-plasma-exposed samples