24P057-P

Evaluation of deuterium dynamics in materials with device of Plasma Surface dynamics with Ion Beam Analysis (PS-DIBA)

イオンビーム解析を用いたその場計測装置PS-DIBAによる
材料中での重水素動的挙動の評価

Masato Yamagiwa[1], Yuki Nakamura[1], Noriaki Matsunami[2], Makoto Takagi[1], Noriyasu Ohno[1], Shin Kajita[2], Masayuki Tokitani[3], Suguru Masuzaki[3] and Akio Sagara[3]
山際　正人, 中村　祐貴, 松波　紀明, 高木　誠, 大野　哲靖, 梶田　信,
時谷　政行, 増崎　貴, 相良　明男

[1]*Department of Energy Engineering and Science, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan*
名古屋大学大学院工学研究科 〒464-8603　名古屋市千種区不老町
[2]*Ecotopia Science Institute, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan*
名古屋大学エコトピア科学研究所 〒464-8603　名古屋市千種区不老町
[3]*National Institute for Fusion Science, Oroshi-cho 322-6, Toki, Gifu 509-5292, Japan*
核融合科学研究所 〒509-5292　土岐市下石町322-6

We developed a new compact divertor plasma simulator PS-DIBA (Plasma Surface Dynamics with Ion Beam Analysis), a device which makes it possible to carry out in-situ ion beam analysis of deuterium retention under high density plasma irradiation, relevant to divertor plasma conditions. Dynamic behavior of deuterium retention in tungsten was investigated during and after plasma exposure by using Nuclear Reaction Analysis (NRA) in PS-DIBA. Decay time of deuterium retention of ITER grade W after plasma disappearance was about 5 hours, which was much shorter than that of powder metallurgy tungsten (40 hours). The result indicateed that the decay time could be different depending on manufacturing methods for W.

1. Introduction

Control of hydrogen isotope retention in plasma-facing components (PFC) is essential to establish steady-state operation. In particular, tritium retention inside the vacuum vessel poses serious problem in the operation of the ITER to give a limit of the number of plasma discharges. Therefore, the prediction of dynamic behavior of hydrogen isotope retention behavior in PFC is considerable for practical purpose. The dynamic retention leads to several effects, such as hydrogen recycling and net erosion of plasma-facing surfaces. Especially, important issues related to dynamic retention are Optimization of the timing of fueling and Flux dependence of chemical sputtering. However, these phenomena remain relatively poorly understood, primarily due to the lack of proper plasma-surface analyses except for a few devices [1-3].

Hence, we have developed a device called 'Plasma Surface Dynamics with Ion Beam Analysis' (PS-DIBA) including nuclear reaction analysis (NRA), elastic recoil deflection (ERD) to investigate the dynamic retention property in divertor plasma environments. By using the PS-DIBA, the temporal evolution of deuterium retention on tungsten was investigated during and after plasma irradiation.

2. Experiments

Figure 1 shows a schematic of the PS-DIBA device. The steady state plasma was produced with a DC arc discharge using a zigzag-shaped LaB_6 cathode, which was heated up to 1500 K by direct-current Joule heating. Anode is made of a copper tube cooled by water. Discharge gases are introduced between the two cathodes, contributing to an efficient usage of the neutral gas for the discharge.

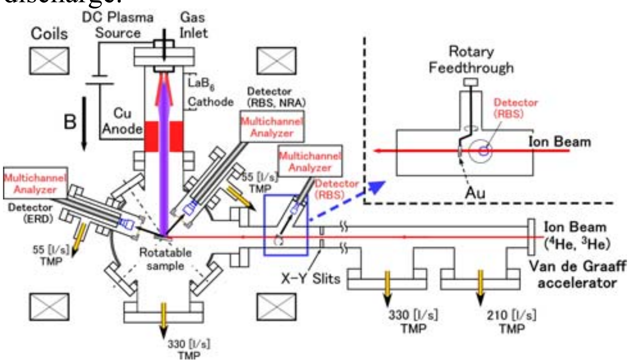

Fig.1 Schematic top view of PS-DIBA device.

Figure 2 shows the discharge power dependences of electron density, n_e, and temperature, T_e, at the center for a plasma column. In helium plasma, n_e reaches 1.1×10^{19} m^{-3} at the discharge power of 2.7 kW. The incident ion energy can be controlled by electrically biasing the sample.

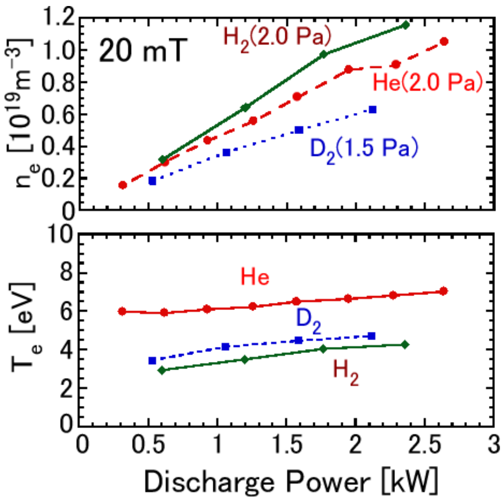

Fig.2 Discharge power dependence of the electron density n_e and electron temperature T_e.

The deuterium retention in sample were analyzed by NRA of 1.0 MeV D(^{3}He,p)α using a Van de Graaff accelerator. The solid-state detectors for NRA is sealed by mylar film to maintain high vacuum state and Al film is also used to repel plasma photons. A rotating gold plate was equipped between the sample and the beam exit and used for a beam chopper, where the beam current was monitored by using RBS.

3. Experimental Results

ITER grade tungsten was used for specimens. Figure 3 shows the irradiation sequence with an initially fresh tungsten sample. The plasma parameters were gradually changed in Fig. 3(b). The retention was determined by integrating the measured D concentration over the entire detection depth. The measurement result in the present study [4] also represents a similar tendency, indicating the retention amount is dependent primarily on the surface temperature. Therefore, precise control of surface temperature is required independently from the plasma condition in future study. After plasma termination, D retention gradually decreased. The desorption time constant was evaluated to be 5.0 (+1.7/-1.1) hours. We have conducted same experiment by using powder metallurgy tungsten (PM-W). The preliminary result of time evolution of D retention for PM-W shows that the desorption time constant is about 40 hours, which is much longer than that in ITER R&D tungsten.

4. Summary

Plasma surface dynamics with ion beam analysis (PS-DIBA) device has been set up on the line at the Van de Graaff accelerator. The dynamic behaviour of deuterium retention on tungsten was investigated

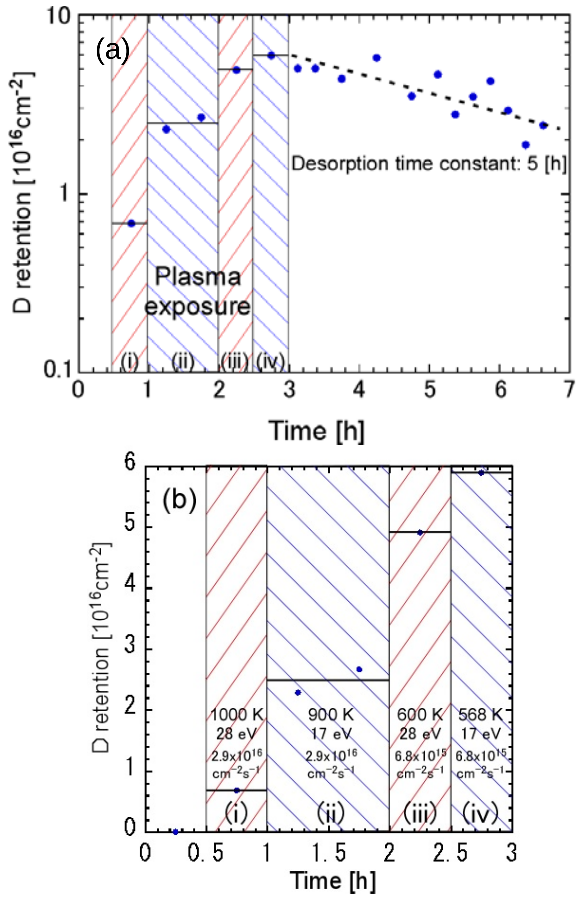

Fig.3 (a) Deuterium retention in ITER grade W measured with NRA. (b) is enlargement of (a) and deuterium plasma exposure conditions.

by using PS-DIBA.The deuterium retention of ITER grade tungsten was mainly determined by sample temperature. The decay time of ITER grade tungsten was shorter than that of PM-W, which suggested that the decay time depends on manufacturing method of tungsten. In this study, because of the lack thermal control, plasma flux was selected to keep the sample temperature low.

Acknowledgments

This work is performed with the support and under the auspices of the NIFS Collaboration Research programs (NIFS08KOBP010, NIFS11KLEF003).

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