20pC2-1

Hydrogen Recycling Study Utilizing an End Region in GAMMA 10/PDX

GAMMA 10/PDXにおけるエンド領域を活用した水素リサイクリング研究

Mizuki Sakamoto[1)], Kensuke Oki[1)], Motoki Yoshikawa[1)], Akihiro Terakado[1)], Ryo Nohara[1)], Kunpei Nojiri[1)], Masanori Mizuguchi[1)], Yousuke Nakashima[1)], Masakatsu Fukumoto[2)], Kazuya Ichimura[1)], Yasunori Hosoda[1)], Keita Shimizu[1)], Junko Kohagura[1)], Masashi Yoshikawa[1)], Tsuyosi Imai[1)] and Makoto Ichimura[1)]

坂本瑞樹[1)], 大木健輔[1)], 吉川基輝[1)], 寺門明紘[1)], 野原涼[1)], 野尻訓平[1)], 水口正紀[1)], 中嶋洋輔[1)], 福本正勝[2)], 市村和也[1)], 細田甚成[1)], 清水啓太[1)], 小波蔵純子[1)], 吉川正志[1)], 今井剛[1)], 市村真[1)]

[1)]Plasma Research Center, University of Tsukuba
1-1-1, Tennodai, Tsukuba, Ibaraki 305-8577, Japan
筑波大学プラズマ研究センター 〒305-8577 茨城県つくば市天王台1-1-1
[2)]Japan Atomic Energy Agency, 801-1, Mukouyama, Naka-shi, Ibaraki 311-0193, Japan

In GAMMA 10/PDX, studies on the boundary plasma and plasma surface interaction have been done using the divertor simulation experimental module (D-module) making best use of the tandem mirror device. The V-shaped tungsten target in the D-module is exposed to the end loss plasma. The effect of additional hydrogen gas supply on the recycling is investigated, indicating that molecular activated recombination occurs inside the V-shaped target. The target temperature is increased up to 573 K with sheath electric heaters, suggesting enhanced hydrogen recycling due to increase in the target temperature.

1. Introduction

In the tandem mirror GAMMA 10/PDX, recently, a new project has been promoted to study the boundary plasma and plasma surface interaction (PSI). The divertor simulation experimental module (D-module) has been installed in the end region of the mirror device to make best use of a linear plasma device with plasma confinement. The features of GAMMA 10/PDX for the boundary plasma and PSI studies are the following: (1) high ion temperature of the plasma exposed to the D-module (i.e. a few hundreds eV), (2) high magnetic field (0.15 ~ 1.5 T), (3) large plasma size (0.1 ~ 0.3 m), (4) low background pressure in the vacuum vessel and (5) high controllability of the plasma exposure since plasma heating systems of ECH, ICH and NBI are equipped. Noted that ion energy of the plasma is distributed, meaning that condition of PSI is equivalent to that of the torus plasma from a viewpoint of hydrogen recycling.

2. Experimental Setup

The D-module is installed in the west end region of GAMMA 10/PDX and it can be moved up and down. In the case of a divertor simulation experiment, the D-module is moved up and set on the axis of the plasma.

The D-module consists of a rectangular box (0.5 m square and 0.7 m in length) with an inlet aperture at the front panel and a V-shaped target inside the box as shown in Fig.1. Tungsten target plates with the thickness of 0.2 mm are attached on the V-shaped base made of Cu. The target size is 0.3 m in width and 0.35 m in length. The length between the front edge of the target and the inlet of the D-module is about 0.3 m. The open-angle of the V-shaped base can remotely be changed from 15 degrees to 80 degrees. The sheath electric heaters are attached on the backside of the Cu base to control the target temperature (T_{target}) up to 573 K. Besides, additional hydrogen gas can be supplied near the inlet of the D-module.

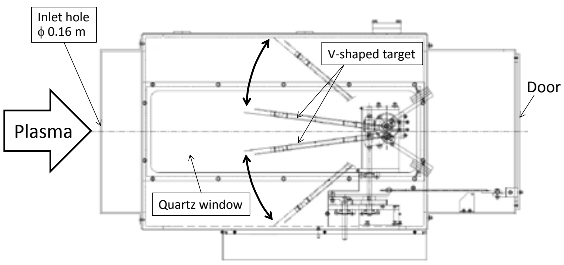

Fig. 1 Schematic view of the D-module.

For the plasma characterization, thirteen Langmuir probes have been installed on the upper target plate and two probes have been installed at the upstream from the front edge of the V-shaped target. The electron temperature (T_e) and electron density (n_e) have also been evaluated from He I line intensity ratio (He I (728.1 nm)/He I (706.5 nm) and He I (667.8 nm)/He I (728.1 nm)) using a collisional-radiative model for a neutral helium. A small amount of He gas is supplied from the nozzle located on the upper target plate. Besides, spectroscopy and fast camera measurements have been done.

Moreover, another tungsten target plate with the diameter of 100 mm can be used to study the hydrogen recycling. In this case, only the tungsten circular plate is set on the axis of the plasma in the west end region.

3. Experimental Results

In this study, we have carried out 3 kinds of experiments to study hydrogen recycling: (1) hydrogen gas supply experiment, (2) high temperature target experiment and (3) hydrogen reflection experiment. The open angle of the V-shaped target was 45 degrees.

In order to study dependence of hydrogen recycling on the neutral pressure, hydrogen gas was supplied near the inlet of the D-module. The pressure of the gas tank for the gas supply (i.e. plenum pressure) was changed up to 1000 mbar and then the neutral pressure increased up to 1.23 Pa. The neutral pressure was measured with an ASDEX gauge. As shown in Fig.2, the electron density near the inlet of the D-module (~0.23 m upstream from the front edge of the V-shaped target) continued to increase from 0.3 x 10^{17} m^{-3} to 3 x 10^{17} m^{-3} and the electron temperature decreased from 33 eV to 10 eV as the additional hydrogen gas was supplied. At that time, the electron density on the target (0.175 m from the corner of the target) increased up to 2 x 10^{17} m^{-3} at P ~ 0.4 Pa and then it decreased to ~0.6 x 10^{17} m^{-3}, and the electron temperature decreased from 34 eV to ~3 eV, suggesting the detachment occurred near the corner of the V-shaped target. Moreover, the dependence of the H_α and H_β line intensities on the neutral pressure suggests that molecular activated recombination (MAR) occurred near the corner of the V-shaped target.

The effect of wall temperature on hydrogen recycling is one of the most important issues for particle balance study. We have investigated this effect using the temperature-controlled V-shaped target. Figure 3 shows dependence of the electron density on the target and the H_α line intensity inside the target on the target temperature (T_{target}). The target temperature was increased up to 573 K shot by shot. It is found that the intensities of balmer lines inside the V-shaped target and the electron density increased with increase in T_{target}, indicating that the recycling was enhanced due to increase in the target temperature.

A tungsten disk target with the diameter of 0.1 m was exposed to the end loss plasma in the west end region. Noted that the D-module was not utilized in this experiment. The H_α line intensity in front of the target decreased exponentially with distance from the target. There are two exponential components: one is short decay length ~ 10 mm and the other is long one ~ 80 mm. Both lengths are too short for hydrogen atoms reflected on the wall and dissociated from the molecule, if they are ground state. A possible candidate for the observed short decay length would be that a fraction of the reflected atoms are at an excited state.

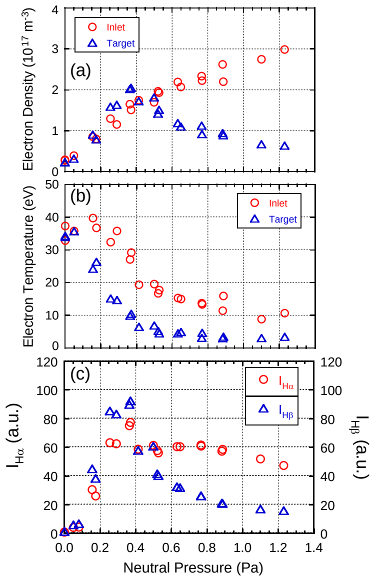

Fig. 2 (a) Electron density near the inlet and on the target and (b) H_α and H_β line intensities as a function of neutral density in the D-module.

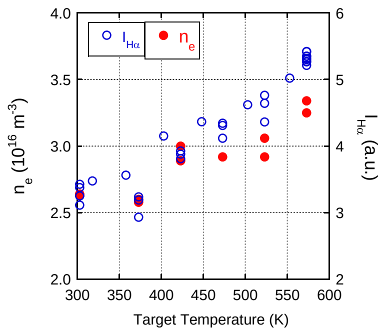

Fig. 3 Electron density on the target and H_α line intensity as a function of the target temperature.

Acknowledgments

This work is performed with the support and under the auspices of the NIFS Collaboration Research program (NIFS13KUGM083, NIFS14 KUGM086, NIFS13KEMF049).