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Generation and characterization of detached plasma in the GAMMA 10/PDX end-cell

GAMMA 10/PDXエンド部における非接触プラズマ形成とその特性評価

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This paper describes the recent results of divertor simulation research towards the generation and characterization of the detached plasmas performed in the GAMMA 10/PDX end-cell. Massive gas injection (H_2 and noble gases) into the divertor simulation experimental module (D-module) was carried out and we have succeeded in achieving detachment of high temperature plasma equivalent to the SOL plasma of tokamaks. A remarkable reduction of the electron temperature (from few tens eV to < 3 eV) on the target plate was successfully attained associated with the strong reduction of particle and heat fluxes. Simultaneous injection of noble gas and hydrogen gas showed the most effective results on detached plasma generation, which indicates the effect of molecular activated recombination (MAR) processes.

1. Introduction

In future fusion devices, formation of detached plasma is a key issue in their operation. In Plasma Research Center of the University of Tsukuba, the E-divertor project has been started [1, 2]. The aim of this project is to study divertor simulation under the condition closely resemble to actual plasma confinement devices and to solve important research subjects toward the stable control of the detached-plasma. GAMMA 10/PDX is a large-scale linear device with 27 m in length.

Recently, intensive divertor simulation experiments were started using a divertor simulation experimental module (D-module) newly installed at the exit of west end-cell [3]. In this paper, the recent results of divertor simulation experiments for the detached plasma formation is described on the basis of the experimental results.

2. Experimental setup

GAMMA 10/PDX is the largest tandem mirror device with minimum-B anchor and consists of four sections, from the central to the end. In Fig. 1(a) the schematic view of the vacuum vessel and the shape of the plasma in the west end-mirror region of GAMMA 10/PDX is shown together with the location of the diagnostic equipment. In divertor simulation experiments, D-module is moved up on axis close to the end-mirror exit. In this experimental module, two tungsten plates are mounted in V-shaped with their variable open-angle from 15° to 80°. D-module is equipped with gas injection system for investigating radiation cooling mechanism for the generation of plasma detachment in D-module. Arrays of Langmuir probes and calorimeters are installed on the each upper and lower tungsten plates, respectively. A pair of calorimeter and Langmuir probe is also located behind a small gap of the V-shaped corner for measuring the degree of detachment plasma detachment. In both end-cells, arrays of multi-gridded type ion energy analyzer (ELIEA) are installed for measuring the flux of end-loss ions.

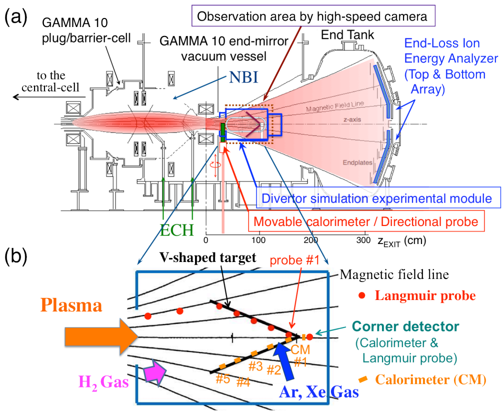

Fig.1. Schematic view of the experimental setup. (a) Vacuum vessel of the GAMMA 10/PDX west end-region and diagnostics for the divertor simulation experiments. (b) Divertor simulation experimental module (D-module) and the location of diagnostics.

3. Experimental results and discussion

The first experiment for realizing detached plasma state from the high-temperature plasmas has been performed using gas injection in D-module. Here, the plasma with $n_e \sim 2\times10^{18}$ m^{-3} and $T_{i//} \sim 150$ eV was produced at the upstream region (central-cell). Gas injection was carried out 0.3 s ~ 0.8 s before the plasma discharge. Quantity of gas injection is controlled by changing the plenum pressure of the reservoir tank. In Fig. 2, the time behavior of the ion saturation current $I_{i\text{-sat}}$ measured with a directional probe installed behind the corner is shown in the case with H_2 and Xe gas injection into D-module. With increasing the amount of the Xe gas injection, $I_{i\text{-sat}}$ clearly decreases and shows a strong reduction to 15 % of that without gas injection. Especially, in the case of simultaneous injection of both Xe and H_2, ion flux is drastically reduced to less than 3 %. From these phenomena, it is confirmed that the plasma detachment is caused by massive gas injection into D-module.

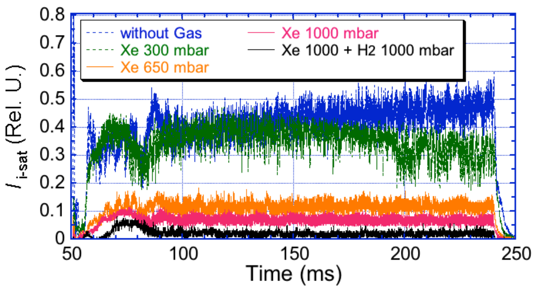

Fig.2. Time behavior of ion saturation current measured at the V-shaped corner the in Xe gas injection experiment in D-module.

The dependence of the plasma parameters measured in D-module is investigated on the amount of gas injection. In Fig. 3, the electron temperature T_e^{Div}, the density n_e^{Div} measured by the probe #1 on the upper target plate and $I_{i\text{-sat}}$ behind the corner are plotted as a function of the plenum pressure of the gas reservoir. In this experiment, the increase of n_e^{Div} and reduction of T_e^{Div} firstly occur due to the Ar injection. Then the decrease of ion flux and n_e^{Div} are observed according to the increase of injecting H_2 gas. On the other hand, T_e^{Div} is already decreased to ~3 eV in the stage of the Ar gas injection and $I_{i\text{-sat}}$ continues to decrease in spite of no further reduction in T_e^{Div} during H_2 injection. From the above results, it is suggested that the hydrogen molecules play an important roll in promoting recombination processes, which lead to achieving the plasma detachment in D-module. Taking account of the result that measured T_e^{Div} is 2~3 eV, the molecular activated recombination (MAR) process may be dominant in achieving detached plasma formation from the same reason with the H_2 injection experiment.

More detailed results and further discussion will be presented in the conference.

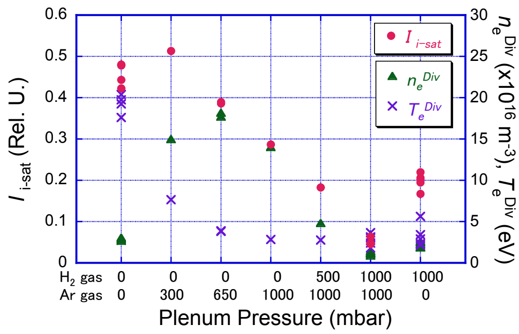

Fig.3. Ion saturation current, electron density and temperature measured in D-module as a function of the plenum pressure of injected hydrogen and Ar gases.

Acknowledgments

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