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Steady State Production of Recombining Plasma in DT-ALPHA
直線型RFプラズマ源DT-ALPHAにおける再結合プラズマの定常生成実験

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Steady state gas-puffing experiment is carried out in a radio frequency plasma source, DT-ALPHA. To prevent secondary gas from affecting the plasma production, three orifices are installed. The neutral pressure at a test region is changed from 0.3 Pa to 21 Pa. In the pressure below $p \leq 3$ Pa, the electron density increases due to the electron collision ionization. In the high pressure regime, both the electron temperature and density decreases as the neutral pressure increasing. Those results are obtained in a steady state plasma, which suggests that the experimental device is suitable for long time-exposing spectroscopy of recombining plasma study and for transient beam-injection experiments.

1. Introduction

Detachment operation of the divertor plasma using volumetric recombining processes is required for steady state fusion reactors. While fundamentals of the volumetric recombining plasma has been understood using many divertor plasma simulators [1-3], what should be studied is sustainability of steady state detached plasmas against transient heat and particle fluxes. Since a beam component injection penetrating through a plasma source is a suitable method for such a study, we have started to produce a steady state recombining plasma using a radio frequency (RF) plasma source instead of the direct current (DC) arc discharge sources.

In our previous experiments [4], a sudden drop of the ion saturation current was observed when a secondary gas was puffed into a test region. However, the phenomenon was transient due to a leakage of the secondary gas to a plasma production region. In order to sustain a steady state high neutral-pressure environment in the test region, orifices have been installed in the experimental device. In this paper, experimental results of a steady state gas puffing operation are presented in terms of a pressure dependence and a radial profile.

2. Experimental setup

Experiments are performed in a linear RF divertor plasma simulator, DT-ALPHA [5]. A schematic of the DT-ALPHA device is shown in Fig. 1. Total length of the device is about two meters. Vacuum vessel consists of a stainless steel (SUS) chamber and a quartz pipe. There are 10 coils to produce a magnetic field. The magnetic field strength is up to 0.2 T. Helium working gas is supplied into the DT-ALPHA device through upstream end-plate, flow rate of which is controlled with a mass flow controller. In addition, helium secondary gas is supplied in a test region for high pressure experiments. To prevent secondary gas from affecting the plasma production, three orifices made of SUS are installed in the DT-ALPHA device, of which dimensions are 20 mm in diameter and 110 mm in length. Three turbo molecular pumps are equipped. Two of them are placed at the both end of the device and one is placed between the orifices. To produce a plasma, a 13.56 MHz RF oscillator, whose maximum power is 3 KW, is used. Measurements of the plasma parameters were performed using the double probe method at the test region as shown in Fig. 1.

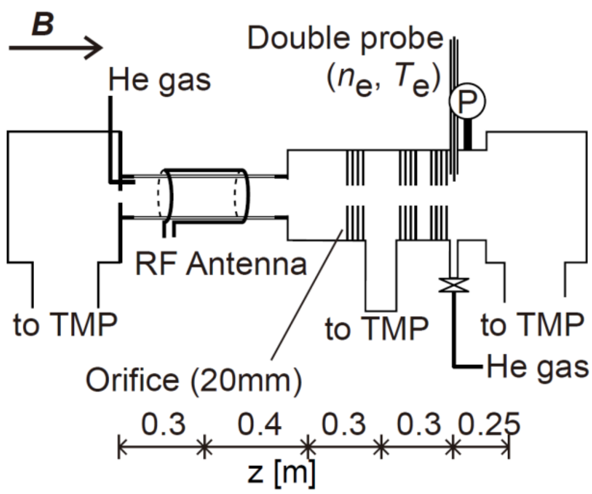

Fig. 1. A schematic of the DT-ALPHA device.

3. Experimental results

Experiments using helium plasma with helium secondary gas puffing were performed. The pressure dependence of the electron temperature and density measured at the test region are shown in Fig. 2. The horizontal axis represents the neutral pressure measured at the test region. The electron temperature monotonically decreases from 12 eV to 2 eV when the pressure increases from 0.3 Pa to 21 Pa. On the other hand, the electron density increases from 2.9×10^{16} m^{-3} to 3.1×10^{17} m^{-3} in a low pressure region then it decrease to 5.5×10^{16} m^{-3} as the pressure increases. In the low pressure region below $p \leq 3$ Pa, the increasing electron density is considered as a result from the electron collision ionization in the test region. Since the variation of the electron temperature is small, the ionization frequency is proportional to the neutral density. In the high pressure region over $p > 3$ Pa, possible processes of the decreasing electron pressure are radiation and diffusion losses. Detailed investigation including a spectroscopic measurement is on going.

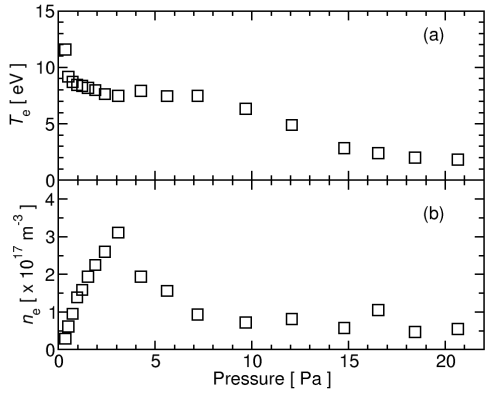

Fig.2. Neutral pressure dependence of the electron temperature(a) and density(b) obtained at the test region, r = 0 mm.

Figure 3 shows radial profiles of the electron temperature and density measured at the same axial position as those shown in Fig. 2. Closed and open squares are obtained in the case of p = 21 Pa and p = 0.3 Pa at the test region, respectively. The profile of the electron temperature is unchanged against the neutral pressure variation. A ratio of the two electron temperature profile is about 5 throughout the plasma column. On the other hand, it is revealed that the profile of the electron density changes between these two pressures. In the high pressure operation, the peak position of the profile somewhat shifts to about 3 mm downward (r = −3 mm). A plateau is also observed at r = 0 − 5 mm.

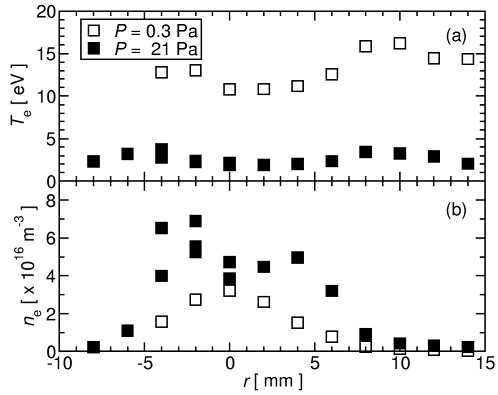

Fig.3. Radial profiles of the electron temperature(a) and density(b) with (closed squares) and without (open squares) gas puffing obtained at the test region.

4. Summary

Steady state gas-puffing experiment is carried out in the DT-ALPHA device. Changing the neutral pressure at a test region from 0.3 Pa to 21 Pa, electron temperature and density is measured. In the pressure below $p \leq 3$ Pa, the electron density increases due to the electron collision ionization. In the high pressure region, both the electron temperature and density decrease as the neutral pressure increasing. Those results are obtained in a steady state plasma, which suggests that the experimental device is suitable for long time-exposing spectroscopy of the recombining plasma study and for transient beam-injection experiments.

Acknowledgments

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