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High Density Plasma Production by a Particle Injection Electrode in TU-Heliac
東北大学ヘリアック装置における粒子注入型電極による高密度プラズマ生成実験

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In the Tohoku University Heliac (TU-Heliac), the high density plasma (~10^{19} m^{-3}) was successfully produced with a particle injection electrode biasing in Helium working gas. The threshold in the neutral working gas pressure on the high density plasma production was also observed. The measurements of a radial profile were performed by the spectroscope with interference filters in virtue of successive high density shots.

1. Introduction

Stellarators have no hard limit of the high density, which is one of great advantages in fusion reactors [1]. In the Tohoku University Heliac (TU-Heliac), which is one of stellarators, we have been trying to produce high performance plasmas. With a hot cathode electrode biasing, we showed the role of the radial electric field for the improved confinement mode [2]. In addition, with the particle injection electrode biasing, we produced the high density plasma (>10^{19} m^{-3}) with working gas Argon [3]. In the present work, we changed the working gas to Helium, which has the smaller sputtering effect than Argon, and successfully produced the high electron density similar to that in case of Argon and succeeded in successive high density plasma productions.

2. Experimental Setup

The TU-Heliac is one of heliac devices (major radius R = 0.48 m, average plasma radius a = 0.06 m and toroidal magnetic period n = 4). The TU-Heliac consists of three sets of coils, and the magnetic field on axis B_0 is 0.3 T. The vacuum vessel was filled with a working gas before discharges. The target plasma was produced by Joule heating with an 18.8 kHz alternating current in additional poloidal coils. The main diagnostic system was a triple probe for measuring electron density. In addition, we prepared the spectroscope composed of three interference filters (center wavelengths: 468.6 nm, 667.8 nm and 728.1 nm).

The experimental set-up of the particle injection electrode is shown in Fig. 2. The electrode was made of palladium coated with gold (Pd-Au). Before discharges, the Pd-Au electrode was immersed in hydrogen gas (p_{in} ~ 20 kPa) at room temperature for about 18 hours in the upper chamber (conditioning chamber) separated from the vacuum vessel by the gate-valve. After the conditioning, the decrease of hydrogen gas pressure Δp_{in} in the chamber was about 10 kPa.

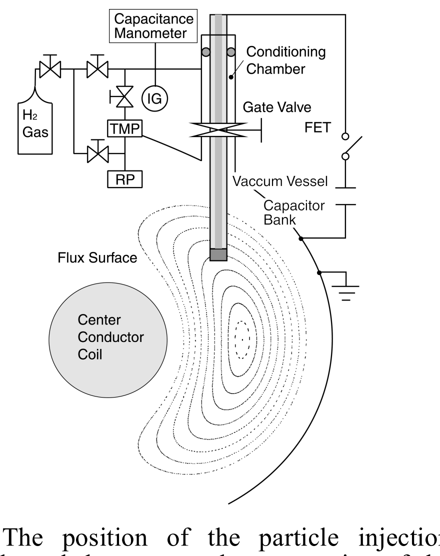

Fig.1. The position of the particle injection electrode and the computed cross-section of the vacuum magnetic flux surfaces at toroidal angle $\phi = 0^\circ$.

3. Experimental results

The Pd-Au electrode inserted into the plasma at $\rho \sim 0.3$ was biased negatively. In the experiment, two series (shot number 81830 ~ 81859, 81860 ~ 81895) were performed. Figure 2 shows the electron density n_e measured by the triple probe at $\rho \sim 0.58$. We successively produced the high density ($\sim 8\times10^{18}$ m^{-3}) plasma discharges over 20 times similar to that in case of Argon. The density in case of the Pd-Au electrode was about twice of that in case of the hot cathode electrode (LaB_6).

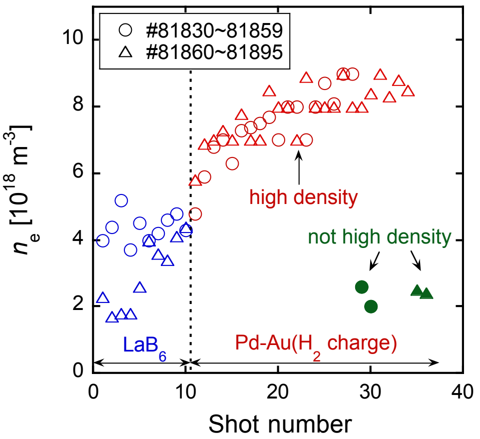

Fig.2. The electron density in the series of the high density production experiments. The first ten shots of the series were discharges with the hot cathode (LaB_6). From 11th shot, circle and triangle symbols show the high density shots and filled symbols show the low density shots.

Figure 3 shows the neutral gas pressure p_{gas_in} before discharges, which was the summation of the Helium working gas pressure and the Hydrogen gas pressure desorbed from the Pd-Au electrode. In Fig. 2, it is clear that the neutral gas pressure increased rapidly at the beginning of the discharge with the Pd-Au electrode, and then decreased gradually. The high density plasma was not produced in the condition below $p_{gas\_in} \sim 7\times10^{-2}$ Pa. This result shows the threshold in the neutral gas pressure on the production of high density plasmas.

As described above, we succeeded in the high density plasma production enough to measure a radial profile of plasma. And we tried to measure the density profile by the spectroscope with interference filters. Figure 4 shows radial profiles of the emission intensities, which had a peak around $\rho \sim 0$. The calculation of intensity ratio of the emissions from the neutral Helium (I(667.8 nm)/I(728.1 nm)) with the Collisional Radiative model [4, 5] allows us to estimate an electron density of plasma.

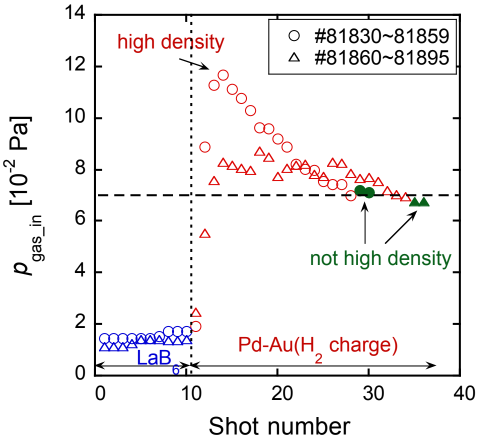

Fig.3. The neutral gas pressure through the series.

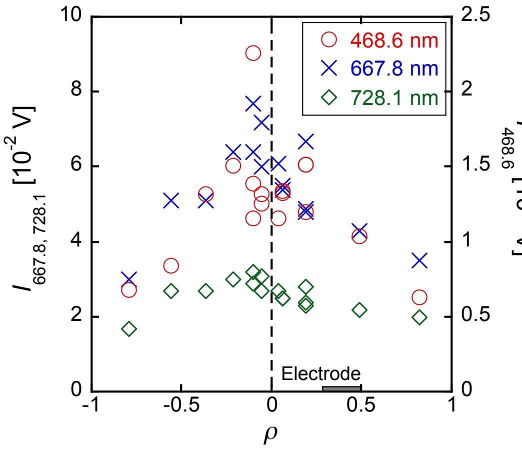

Fig.4. The radial profiles of the emission intensities (center wavelengths: 468.6 nm, 667.8 nm and 728.1 nm) measured by the spectroscope with interference filters.

4. Summary

We successfully produced the high density plasma ($\sim 8\times10^{18}$ m^{-3}) discharges over 20 times with the working gas Helium and observed the threshold in the neutral gas pressure on the high density plasma production. Utilizing successive high density shots, we measured radial profiles of the He emission intensities by the spectroscope with interference filters.

Acknowledgments

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References

[1] A. Iiyoshi *et al.*: J. Plasma Fusion Res. **85** (2009) 487
[2] S. Kitajima *et al.*: Nucl. Fusion **46** (2006) 200
[3] H. Utoh *et al.*: J. Plasma Fusion Res. SERIES **8** (2008) 1052
[4] T. Fujimoto: J. Quant. Spectrosc. Radiat. Transfer **21** (1979) 439
[5] M. Goto: J. Quant. Spectrosc. Radiat. Transfer **76** (2003) 331