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大口径ヘリコンスラスタ開発に向けた2MHz帯RFプラズマ源開発
Development of a 2 MHz band RF plasma source for large diameter helicon plasma thruster

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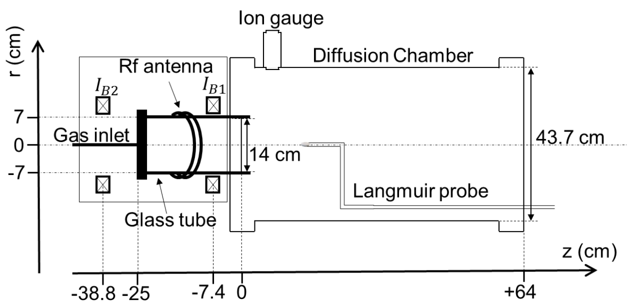
The number of space missions has dramatically increased in recent years and a technology for massive space transportation is required to construct large-scale structures in space, e.g., Space solar power system. Therefore, an electric propulsion (EP) operated at a higher power level is required to perform such a mission. Since the erosion of electrodes and the performance degradation of the neutralizer over time in conventional EP devices limit the lifetime of the system, the development of a helicon plasma thruster (HPT), which is the electrodeless system and could be operated at a high electric power level, is now under investigation [1].

The previous model and experiment have demonstrated that the thruster performance in terms of the thrust-to-power ratio, the specific impulse, and the thruster efficiency, can be improved by enlarging the source diameter [2], where the model is based on the combination between a global plasma source model and a one-dimensional plasma expansion model in a magnetic nozzle [3]. Furthermore, the thruster efficiency approaching twenty percent has been obtained by one of the authors in recent years [4].

In the present study, a large diameter of 14-cm helicon plasma source is developed to improve the performance of the HPT. However, in general, the RF electromagnetic field cannot penetrate to the central region of the cylindrical plasma due to a skin effect, which depends on the RF frequency and the plasma density. When operating at high power with a commonly used 13.56 MHz RF generator, high density plasma tends to be generated near the source wall [4] and immediately lost to the wall [5]. Furthermore, since a gas inlet is generally placed at the radial center of the source back wall, well-penetrated electromagnetic fields can efficiently ionize the injected propellant flowing in the central region. To overcome such a problem, as shown in Fig.1, a 2 MHz RF generator is chosen as the power source and attached to a 14-cm-diameter helicon source which is further contiguously attached to the diffusion chamber. The profiles of the plasma density, the electron temperature, and the plasma potential in the source and the diffusion chamber are experimentally investigated.



The experimental results show that the plasma density in the source is $\sim 5 \times 10^{18}\ \mathrm{m}^{-3}$ for the RF power of 4 kW, which is in fair agreement with the calculated result from the model. This suggests that high-density plasma is successfully generated. Moreover, an RF power transfer efficiency close to 95% is obtained for the RF power higher than 500 W. The radial profiles of plasma density in the upstream and downstream sides show that the density has the maximum at the radial center. On the other hand, the annular density profile has been often observed for the frequency of 13.56 MHz and been discussed in terms of the skin effect. Therefore, the central density peak for the 2 MHz case implies that the electromagnetic field can penetrate to the central region in the source, compared with the 13.56 MHz case. However, the source is operated at higher pressure than the previous experiments; the detailed comparison will be made in near future.

References

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