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Effect of energetic tail component on a polytropic index of electrons expanding in a magnetic nozzle

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Plasma expansion in a magnetic nozzle (MN) is a key element to develop a high-power electric propulsion device in space, e.g., a helicon thruster. In such a magnetic nozzle thruster, plasma detachment from the closed magnetic field lines is one of the biggest problems[1]; the plasma flow has to be exhausted from the system into the space via the plasma detachment process to obtain a net thrust.[2] Efficiency of the plasma detachment from the MN is considered to have an impact on the propulsion performance. According to Merino and Ahedo, electron cooling characterized by a polytropic index γ is a key process to the plasma detachment.[3] Their analysis has proposed that the detachment efficiency can be improved when the electron cooling is enhanced, i.e., for larger volume of γ.

Previous studies, for on the investigation on the electron thermodynamics in the MN have established the experiment eliminating electric fields in plasma by electron-beam-excited plasma source. The results have shown the adiabatic polytropic index, implying that the electrons do work on the MN and the thrust is enhanced by the MN.[4,5]

When operating the helicon thruster at high power, the helicon wave is excited; an early experiment has demonstrated that an electron beam with the similar energy to the phase velocity of the helicon wave is generated.[6] Therefore, the present study is aimed to investigate the thermodynamics of the electrons having the high energy tail component.

A schematic diagram of the experimental setup in this study is shown in Fig.1. The thermionic electrons emitted from a filament accelerated and injected into a quartz tube and diffusion chamber by applying the discharge voltage V_D. The accelerated electrons induce the electron impact ionization process and create the plasma. Presence of the high energy tail electrons can be controlled by the presence or absence of an anode mesh. Most of the electrons accelerated from the filament flow s into the anode mesh as detected as the anode current in the previous study,[4] while all the electrons are injected into the diffusion chamber when removing the mesh from the system. The nearly Maxwellian electron energy probability function (EEPF) can be obtained for the former case, while the clear electron beam component is detected for latter case. For both the cases the plasma potential is maintained at the potential of less than zero, implying all the electrons escape from the downstream boundary and never turn back to the source.

Axial measurements of the electron energy probability function (EEPF) and polytropic index obtain from the axial profile showed that the polytropic index is close to 5/3 when the high energy electron beam is absent and is close to 2 when the high energy electron beam is present. This indicates that the presence of the high energy tail electrons causes a significant decay in the electron temperature profile. The detailed results will be shown in the presentation.

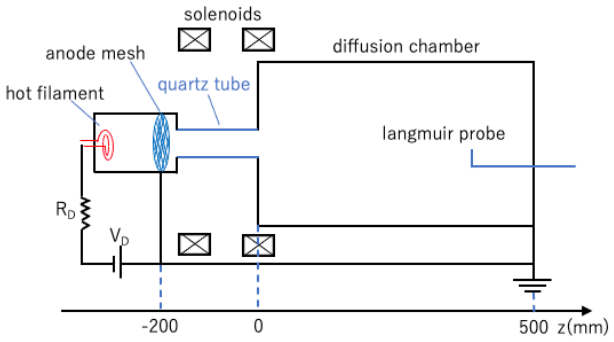

Fig.1 Schematic diagram of the experiment setup.

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