Experimental observation of Ion behavior in an Inductive Radio-frequency Plasma Accelerator

Hokuto Sekine, Hiroyuki Koizumi and Kimiya Komurasaki
The University of Tokyo, Bunkyo-ku Hongo 7-3-1, Tokyo, 113-8656, Japan

Abstract

Acceleration of charged particles via the interaction with a magnetic field is an essential topic for magnetic fusion devices, space plasmas, and plasma thrusters. Electrodeless plasma thrusters can diminish the erosion of the electrodes which is one of the most challenging matters for conventional plasma thrusters, which leads longer lifetime of the propulsion system than that of the existing one. The electrodeless plasma thrusters have a cylindrical source tube made of glass and accelerate plasmas along axial direction toward the open source exit. A variety of combinations of the plasma production and acceleration mechanisms have been proposed. Some of the electrodeless thrusters utilize electromagnetic acceleration. The features of the acceleration are the inductive production of azimuthal current loop/sheet j_θ via an external coil and the plasma acceleration by axial Lorentz force $j_\theta B_r$. Pulsed inductive thrusters (PITs)[1] produces Townsend-like discharge plasmas and accelerate them electromagnetically. Faraday Acceleration with Radio-frequency Assisted Discharge (FARAD)[2] employed rf discharge as pre-ionization to lower the necessary high voltage for PITs to ionize propellant gas. In order to suppress the plasma loss to the wall of the FARAD, Radio-frequency Inductive Accelerator with Low-aspect-ratio Plasma (RIPAL) conducts rf plasma production and acceleration in the same region. In addition to that, it accelerates plasma utilizing low-frequency (*O*(10-100 kHz)) diverging magnetic field instead of pulsed diverging magnetic field aiming the improvement of propellant utilization efficiency. Thrust measurements with a target-type thrust stand showed the thrust-to-power ratio of the RIPAL of ~1 mN/kW. It is considered the physical insight of the electromagnetic acceleration process and resultant momentum transportation gives the key to develop the RIPAL and the other electromagnetic electrodeless plasma thrusters. However, the plasma acceleration mechanisms on the RIPAL have not been resolved enough yet. In this study, the spatiotemporal distributions of azimuthal induced electric current j_θ and radial magnetic field B_r were obtained by B-dot probe measurements. The distributions of the azimuthal currents correspond to the azimuthal electric field, indicating the current formation is mainly derived by the electric field. With the induced current measurements, the plasma acceleration process was investigated by the measurements of the spatiotemporal distributions of ion saturation currents of a Langmuir probe. It was found that the relationship between the azimuthal current formation and resultant plasma acceleration. Moreover, it clearly showed the applied static magnetic field has a great influence on the mechanisms of plasma acceleration.

References

[1] K. A. Polzin, “Comprehensive Review of Planar Pulsed Inductive Plasma Thruster Research and Technology,” *J. Propuls. Power*, vol. 27, no. 3, pp. 513–531, 2011.

[2] E. Y. Choueiri and K. A. Polzin, “Faraday Acceleration with Radio-Frequency Assisted Discharge,” *J. Propuls. Power*, vol. 22, no. 3, pp. 611–619, May 2006.