Improvement of the Thrust Force of the μ10 Microwave Ion Thruster by Optimizing the Potential of the Conductive Wall

IEPC-2015-332／ISTS-2015-b-332

Presented at Joint Conference of 30th International Symposium on Space Technology and Science
34th International Electric Propulsion Conference and 6th Nano-satellite Symposium,
Hyogo-Kobe, Japan
July 4 – 10, 2015

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Abstract: In order to improve the thrust force of the ECR Ion Thruster μ10, a design of a spacer which locates between magnet rings was changed to an anode spacer to improve the ion production cost. The anode spacer had a role to decrease ions which collide with the spacer. In addition, a screen grid was newly isolated from the discharge chamber. As a result, the anode spacer and the isolated screen grid improved the beam current from 170 mA (10 mN) to 191 mA (11.4 mN).

I. Introduction

Japanese asteroid explorer "Hayabusa" was launched on May 9th 2003 and returned to the earth in June 2010 powered by four electron cyclotron resonance (ECR) ion thrusters "μ10" [1)]. Through its mission, the total established operation time is 39,600 hours [2)]. To use the ion thruster μ10 for a successive mission "Hayabusa2", the change of grid's optics and propellant injection ways were conducted. It resulted in the increase of thrust force from 8 mN to 10 mN [3)]. However, the thrust force of the μ10 thruster is still relatively lower than those of DC discharge or RF discharge ion thrusters[4-6)]. One of the reasons of the low thrust of the microwave ion thruster is due to the local plasma production around the strong magnetic field. The design of the magnetic field has been optimized for ECR heating as well as the confinement of the electron. As for DC discharge thrusters, electrons were emitted from a hollow cathode that located at the weak magnetic field region. Hence, the mirror ratio is possibly higher than that of the microwave ion thruster, which results in the uniform plasma production and higher thrust force. In the case of the RF discharge ion thrusters, which utilize magnetic field to accelerate electrons, the discharge chamber walls are

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made of dielectric material. The electron bombardment with the wall drops the potential of the wall. And an anode was used to collect the electron current inside ion sources. The location of the anode inside the ion source has been changed from the upstream of the discharge chamber to the screen grid from 1992 to 2001[6,7]. Compared with those thrusters, the confinement of electrons of the microwave ion thruster is not efficient. The potential of all of the waveguide, the discharge chamber and the screen grid is set at 1.5kV. In this study, the author newly proposes the electric isolation among the above components to limit the area of the anode.

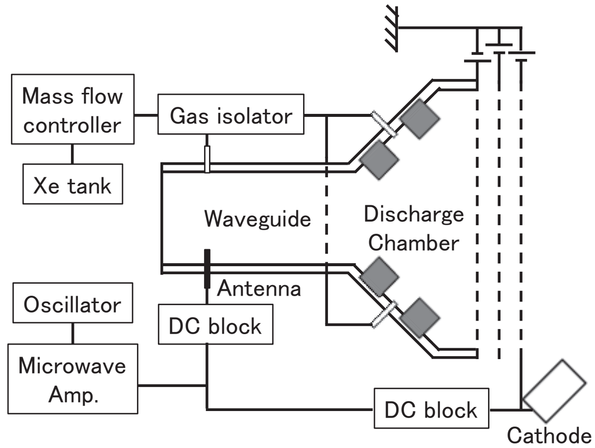

Figure 1 The schematic of the microwave ion thruster μ10

II. Experiment

A schematic of the ECR ion thruster μ10 is shown in Figure 1. Microwave input power was 34 W. The microwave of 4.25 GHz is transmitted from the waveguide to the discharge chamber. In the discharge chamber there are two rings of samarium-cobalt magnet, and the plasma is produce by ECR heating. A propellant, xenon, is injected into the inlet and flows into the discharge chamber, where electrons are continuously accelerated by a mirror magnetic field and microwave electric oscillation by means of ECR. As a result of subsequent electron-neutral collisions, ECR plasma is formed.

Figure 2 shows the location of the anode and the electrical isolation between the screen grid and the discharge chamber. The spacers located between magnets are used as an electrode. Feeding to the anode spacer was done in two ways. One is that only the anode spacer was fed to 1.5 kV and screen grid and discharge chamber were made floating. The other is that screen grid and discharge chamber was fed to 1.5 kV and the anode spacer was fed by another power source, which change the potential of the anode from 1.5 kV to 1.55 kV.

The screen grid was isolated from the discharge chamber by alumina. A thin layer of alumina was coated on the surface of the grid hold ring. Hence, the isolated screen grid had a floating potential when the thruster operates.

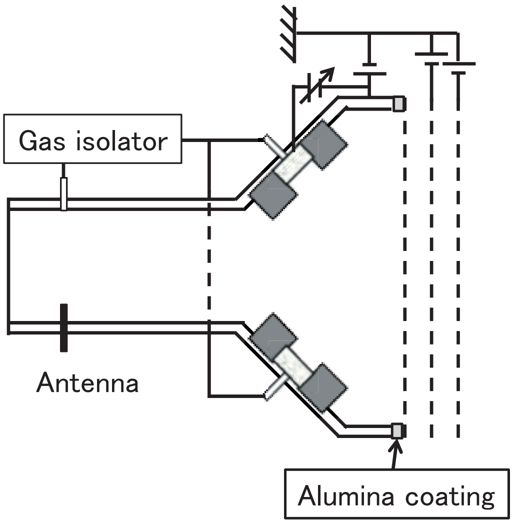

Figure 2 The experimental setup. The spacer has a function of the anode and the screen grid is electrically isolated by alumina.

III. Results and Discussion

Figure 3 shows the beam current with respect to the propellant flow rate. Compared with Hayabusa and Hayabusa 2 models, the beam current increased to 195 mA at 3.3 sccm of Xe flow rates. At this time, the propellant xenon was distributed between the waveguide inlet and the discharge chamber inlets at the ratio of 1:10. And the anode spacer has 1.55 kV of the electric potential. As for more detail, such as the effective of the isolation of the screen grid, its floating potential will be presented at the oral presentation.

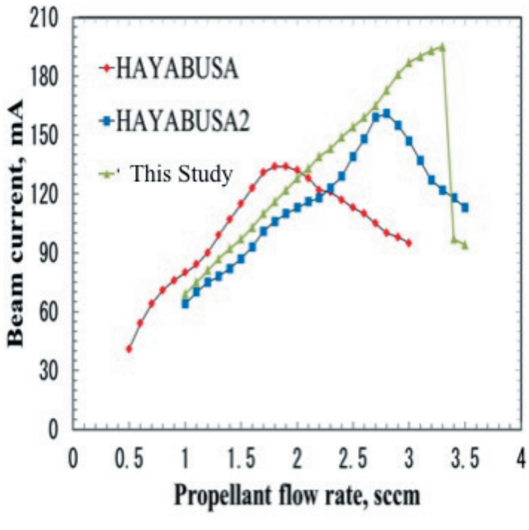

Figure 3 The beam current with respect to the propellant flow rates.

IV. Conclusions

In this study, in order to enhance the thrust force of microwave ion thruster μ10, the anode spacer and the isolated screen grid were introduced. When the anode spacer was set at 1.55 kV, the highest beam current increased to 194 mA, which was equivalent to 11.4 mN at the specific impulse 3050 sec, power consumption 450 W, and at the propulsion efficiency 40%.

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