§35. Development of an Electromagnetic Particle Code for Space Propulsion Application Using ECR Discharge

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The electric propulsion was adopted as thruster for a stationary satellite and a planetary explorer because of its high efficiency. Among the electric propulsion systems, an ion engine electrostatically extracts an ion from plasma. An ion engine with microwave discharge could extend lifetime as compared with DC discharge. In sample return mission MUSES-C of The Institute of Space and Astronautical Science (ISAS), 10cm class microwave discharge ion engine (8mN/400W) is adopted as a main thruster. In addition, this ion engine system has the neutralizer with the microwave discharge.[1)]

Due to improvement of performances for ion engine with the microwave discharge, codes adopting various assumptions are being developed to analyze the plasma behavior and microwave propagation in the ion engine with the microwave discharge.[2)] The purpose of the present study is to analyze plasma behavior and microwave propagation in the 10cm class ion engine and neutralizer. For this purpose, we have developed an electromagnetic particle code. This code is constituted of particle-in-cell (PIC) method to solve the equation of motion for electron and of finite-difference-time-domain (FDTD) method to solve the Maxwell's equation of microwave[3)]. The coupling code can solve the plasma behavior and microwave propagation in a self-consistent manner without complex assumptions. The coupling code is available not only to solve time evolution of the plasma but also to obtain collision and energy distribution function.

Analysis of the microwave propagation has been conducted under boundary conditions as given below:

1) Absorption boundary condition
   An absorption condition is imposed at the end of the discharge chamber. Here, Mur's first absorption condition is adopted [4)].

2) Reflection boundary condition
   Perfect conductor (grid) was assumed at the end of the discharge chamber, so that the electric field which parallel to the boundary plane is set equal to be zero.

In each condition, plasma is not placed in the discharge chamber.

The following results are obtained:

1) In analysis of microwave propagation with altered boundary condition, the traveling wave exists for the absorption boundary. In the reflection condition assuming a perfect conductor, the reflection wave was confirmed in the discharge chamber. But the discharge chamber did not work as resonance cavity. Efficiency of plasma generation is increased when the discharge chamber imposed the reflection boundary condition is optimized to operate as the resonance cavity.

2) In the calculation including plasma, increase of the electron energy was larger for reflection boundary condition than absorption one. Existence of the grid in the microwave ion engine is important in term of reflecting the microwave.

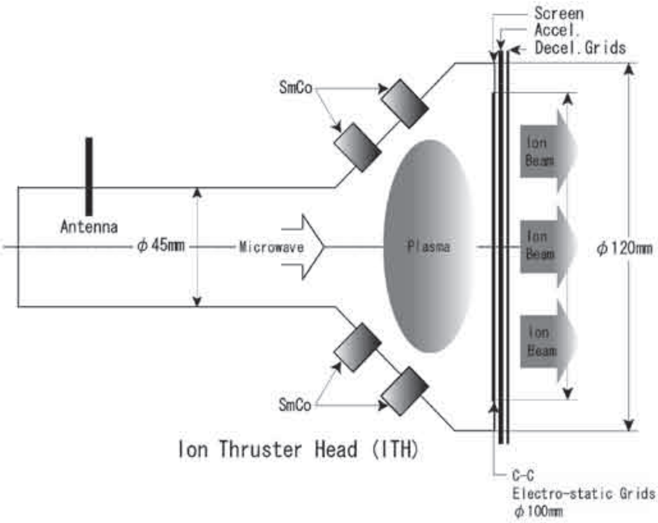

Fig. 1 10cm microwave discharge ion

Reference

1) Toki, K. et al.: "Technological Readiness of Microwave Ion Engine System for MUSES-C Mission", 27th Int. Electric Propulsion Conf, IEPC-01-174 (2001)
2) Hirakawa, M. and Nakakita, M. : "Simulation of Electron Cyclotron Resonance in a Microwave Discharge Ion Thruster", Trans. Japan Aero. Space Sci. 47 (1999) 267
3) Grotjohn, T. A. : "Numerical Modeling of a Compact ECR Ion Source", Rev. Sci. Instrum. 63 (1992) 2535
4) Mur, G., "Total-field Absorbing Boundary Conditions for the Time-Domain Electromagnetic Field Equations", IEEE Trans. Electromagnetic Compat., 40 (1998)100