SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (4)

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NUMERICAL SIMULATION OF MICROWAVE-EXCITED MICROPLASMA THRUSTER WITH HELIUM PROPELLANT

Abstract

In recent years, the trend of space systems has been focused on miniaturization and simplification of the structure, to reduce the mission costs and increase the launch rates. Missions with numerous small-scale satellites, called "nanosatellites", would bring a significant advantage of reducing the mission risk. Such concept has supported a new approach to develop accurate, reliable, and low-cost micropropulsion systems, particularly for high-accuracy station-keeping and attitude control.

In this paper, we report on a microplasma thruster using microwave-excited plasma sources, with emphasis being placed on numerical evaluation of the plasma and nozzle flow characteristics. An advantage of microwave-excited plasmas is that there is no electrode; thus, a serious lifetime problem caused by plasma sputtering is avoided.

The microplasma thruster presently developed consists of an azimuthally symmetric surface wave-excited plasma source and a conical micronozzle for exhausting the plasma. The microplasma source is composed of a quartz chamber, 0.75 − 1.0 mm in radius and 10 mm long, and a metal around the chamber. 4.0-GHz microwaves propagate through a coaxial cable which is connected to the end of the plasma chamber, and then penetrate into the chamber, where the propellant (helium gas) is ionized and heated up by surface waves. The high thermal energy is converted into directional kinetic energy through the nozzle which has a converging and diverging section, to obtain the thrust.

The numerical simulation used in the design process consists of two modules: an electromagnetic module (EMM) and a plasma fluid module (PFM). The electromagnetic fields of microwaves were traced by the EMM employing the finite-difference time-domain (FDTD) approximation to Maxwell's equations, and the plasma evolution was traced by the PFM employing lower-upper symmetric Gauss-Seidel (LU-SGS) scheme for plasma fluid equations.

The plasma characteristics distribution showed that the propellant gas was heated around the inlet of the micronozzle, up to 700 − 1000 K. The thrust and specific impulse were calculated to be 20 − 200 μN and 150 − 350 s, respectively, under the mass flow rate of 10 − 70 sccm and the input power of 2.0 − 8.0 W. These results were in agreement with experimental results using target-type thrust stand and optical emission spectroscopy.