§13. Gridless Plasma Thruster Research

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A plasma thruster using ICRFH is a gridless, highly powerful and variable specific impulse engine. Such a thruster will pave the way for a manned Mars mission 1).

ECR microwave discharge ion thrusters had been investigated for long-distance space missions with the advantages of no cathodes for plasma generation and high specific impulse 2),3). In order to accelerate ions backward, these ion thrusters utilize grids. Their lifetime and driving force depend on grids, and it is difficult to vary their driving force. A gridless ion thruster with antenna for ion acceleration has great potential for a variable-specific-impulse ion thruster with long lifetime and high power 1).

The purpose of our study is to generate plasma with ECRH and to heat ions with ICRFH by using antenna. Heated ions are accelerated backward by a force(proportional to the diverging magnetic field), and accordingly the reacting force is generated in the opposite direction.

We have constructed an experimental apparatus to test the concept 4),5),6).It consists of a cylindrical vacuum chamber (inner diameter of 21 cm and axial length of 150 cm), power supplies and eight magnetic coils. It is run at pressure in the 10^{-4} Torr range with He gas as propellant. Microwave power up to 5.0 kW with a frequency of 2.45 GHz is applied using a magnetron in a continuous wave mode to the resonance area in the vacuum chamber. The propellant is ionized near the resonance region where the electron cyclotron frequency and the microwave frequency are equal (the magnetic field B is 875 G for the microwave frequency of 2.45 GHz), and then plasma diffuses along the magnetic line of force. Produced ions in the plasma are then heated by RF power via dual half-turn antenna with a RF frequency of 252 kHz (ICR magnetic field: $B = 657$ G) The background magnetic field is generated by the magnetic coils.

In the present experiments, two dual-half turn antennas are set in the chamber to control the wave length launched from the antenna. In order to detect the magnetic waves excited by the antenna, we have developed a 3D magnetic probe system. Also are used the Langmuir probes to measure the plasma parameters such as plasma density and electron temperature.

By adjusting the currents in the magnetic coils, a mirror configuration for the magnetic field is produced to confine the plasma and the ECR layer is realized near the gas box. The magnetic field strength between mirrors is set to be higher than that required for the ICR so that we expect to excite ion cyclotron wave. The RF power is launched from the antennas.

For ECR plasma, measurements are made on the plasma parameter to find the plasma density of about 10^{12} cm^{-3} and the plasma radius as 4cm.

Firstly, the RF power is launched from the antenna in the vacuum condition to check the magnetic probe system. Then, we tried to excite ion cyclotron wave in the ECR plasma by the antennas.

We found from the probe measurement that some RF waves are excited in the ECR plasma but we could not conclude them to be ion cyclotron wave 4). Further studies are needed to obtain the final conclusion on the wave excitation and then the ICR heating.

A simulation code was also developed to simulate the wave propagation in the plasma 6).

In summary, we have developed an experimental device to produce plasma by ECR and to accelerate ions in the plasma by ICR heating for simulating the gridless plasma engine. We have as a first experiment tried to excite ion cyclotron wave in the plasma, however we could not obtain the conclusive results on the excitation.

Further studies are in progress on the following topics: (1) to further improve the measurement system to detect ion cyclotron wave, (2) to adopt the rotating antenna such as Nagoya type III for effective ICR heating, and (3) to control the plasma flow by adopting properly designed magnetic coil (i.e. magnetic nozzle) downstream the chamber.

References

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