Design and Construction of a 2.45 GHz Microwave Electrothermal Thruster

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Abstract
A microwave electrothermal thruster has been constructed, consisting of a microwave plasma chamber 12cm long and 8cm in inner diameter and a micronozzle 10mm long with 1mm in diameter. The microwave plasma produced by 2.45GHz microwave frequency at power 1kW and the feed gas is Ar at pressure of 10^-3mTorr. The plasma density and electron temperature are $2.35 \times 10^{17}\ m^{-3}$ and 1.2eV, respectively. The thrust and specific impulse are 10mN and 100s.
Keywords: microwave plasma, electrothermal, thruster, spacecraft.

Introduction
The Microwave Electrothermal Thruster (MET) is an electric propulsion device that converts microwave energy into thermal energy[1,2]. These types of electrodeless thrusters plays an important role in space missions due to their two properties, are:
- limitation of electrode erosion problems
- Ease of speed control in electrodeless motors

So, The MET system was conceived in order to eliminate the handicaps of Resistojets and DC Arcjets. The microwave electrothermal thrusters have low power consumption, small dimensions and their longlifetime operation[1-4].
In this paper, a microwave electrothermal thruster with 2.45GHz frequency at power 1kW is constructed and tested. In Section II, the experimental setup of the work is represented. Section III deals with results and discussion of thruster . The work is concluded in Sec IV.

Experimental Setup
The MET system includes a two endplates (nozzle and antenna), plasma, and a dielectric separation plate. A diagram of the MET thruster is shown in figure 1[5].

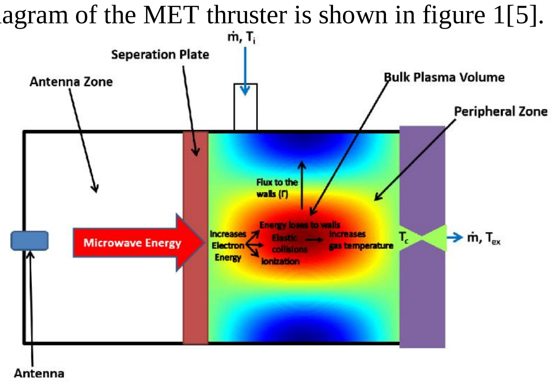

Figure 1. A diagram of the MET thruster [5]

The physical process of MET system can also be explained in the following manner:
Microwave energy are transmitted into the cavity and electrons sre coupled to the electric field of the wave. Thus, the electrons being accelerated by microwave electric fields. Microwave plasma discharge is formed based on the interaction of electrons with neutral gas particles. Then, the plasma acts as a resistive load and with absorbtion of microwave energy, raising the temperature of the gas or plasma. Gas heating increases the gas pressure and released through the nozzle[6,7].
A schematic view of the experimental setup is shown in figure 2. The MET system parameters are listed in table 1.


Figure 2. A schematic view of the experimental setup

Table 1. The MET system parameters

Parameter	Value
Frequency (GHz)	2.45
Power (W)	1
Gas	Argon
Gas pressure (mTorr)	10^-3
Gas flow rate (SCCM)	10-80

Plasma chamber and cavity are made of aluminum and nozzle is made of Stainless steel.

Results and discussion

MET thrusters use 2.45GHz frequency magnetron wave generators because of their availability and low cost[8]. Photos of MET operation and cavity dimensions at 1kW is shown in figure 3.

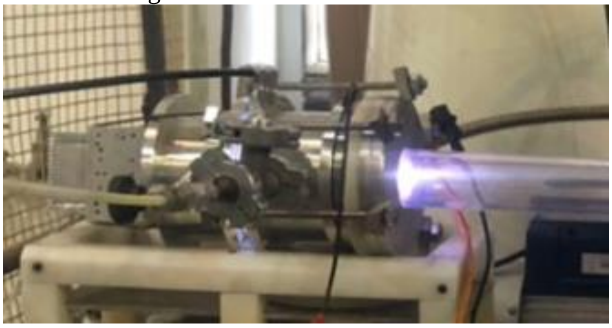

Figure 3. Photos of MET operation and cavity dimensions at 1kW

Using the Langmuir probe, the plasma density is equal to $2.35 \times 10^{17}\ \mathrm{m}^{-3}$ and the plasma temperature is equal to 1.2 eV.

According to the simulation results with COMSOL software, the gas temperature is 3000 K.

According to, the temperature of the chamber, the special impulse can be obtained[1]. And then, the thrust can be calculated by considering the specific pulse range and power[9].

The measured specific impulse of greater than 100s and thrust in range of 10mN was found for argon in this device.

Conclusions

In the paper, we have designed and constructed a microwave electrothermal thruster via a 2.45GHz microwave plasma source at power 1kW.

The results show that this system has a plasma with a density of $2.35 \times 10^{17}\ \mathrm{m}^{-3}$ and a temperature of 1.2 eV. According to the simulation results with COMSOL software, the gas temperature is 3000 K. The thrust and specific impulse are 10mN and 100s.

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