The Latest Development of Low Power Electric Propulsion for Small Spacecraft

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Abstract: In order to increase the control accuracy and the in-orbit lifetime of small satellites, kinds of low power electric propulsion were developed for small spacecraft in LIP(Lanzhou Institute of Physics). Low power electric propulsion contained Vacuum Arcing Thruster (VAT), Pulse Plasma Thruster (PPT), Radio frequency induced Thruster (RIT), and Electron Cyclotron Resonance Assistant Discharge Ion Thruster (ECR) for the power of 1 to 200Watt. This paper will introduce the lasted research progress; include design, experiment and utilization.

I .Introduction

Small and micro satellites have become increasingly popular in recent years as they are significant lower costing, higher reliability, and they are generally more affordable for core commercial applications. Since many microsatellite require propulsion system, miniaturization of the propulsion system is critical in the design of most small and micro satellites [1, 2].In to satisfy the requirement of miniaturization propulsion for different kinds of small satellite,1W class vacuum arcing thruster (LVAT), 5W class Pulse Plasma Thruster (LPPT), 50W class Radio Frequency Ion thrusters (LRIT), and 150 class Electron cyclotron resonance (LECR) ion thruster were developed by LIP(Lanzhou Institute of Physics), in China.

In this paper, the lasted development of low power electric propulsion for small and micro satellites is introduced.

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II. Miniaturization Electric Propulsion Research Activities in LIP

A. The 1W class LVAT

The Vacuum Arc Thruster is a form of low power electric propulsion that operated by the arcing between cathode and anode that driven by pulsed current. The pulsed current is produced by a pulsed power circuit, and the arcing between the electrodes s an inductive discharge. The breakdown between electrodes will form a microscopic sites on the cathode surface is called cathode spot. The spot eject vaporized and ionized material, and the thrust will produced by this material jetting [3]. Figure 1 illustrates the schematic of VAT system.

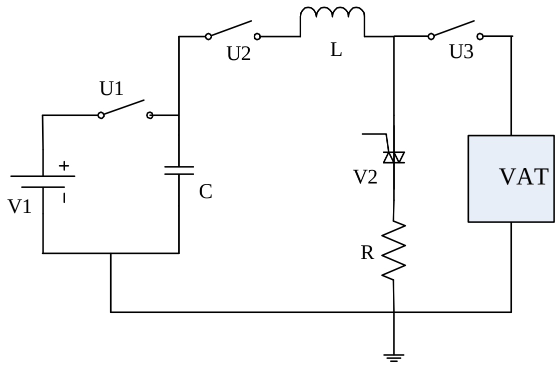


Figure 1. Schematic of VAT system components

Co-axial and Ring-Geometry Vacuum Arc thruster were developed in LIP. Figure 2 is the configuration of the thruster. Figure 3 is thruster head photo. The characterization of the VAT propulsion system contains: (1) the propellant is solid, usually metals, and storage easily, (2) it can be operate over a wide range of pulse frequency, (3) the efficiency will not loss when the input power change in a wide range, (4) the ignition voltage usually less than 1kV, the PPU safety is improved,(5) the VAT system is simple and relatively low mass. So, VAT electric system is better choice for low mass satellite, e.g. small than 10kg or more less.

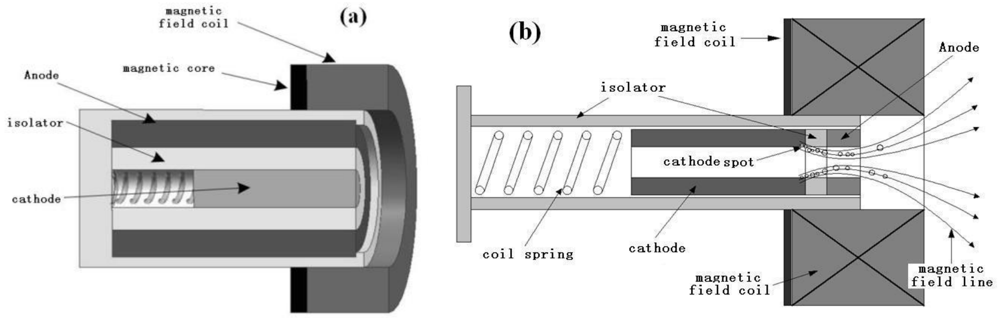
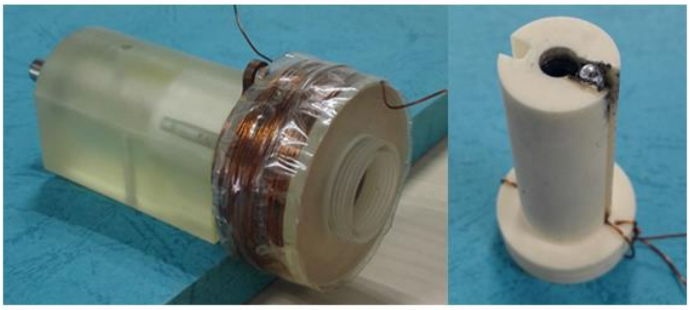


Figure 2. The configuration of co-axial (a) and ring-geometry (b)

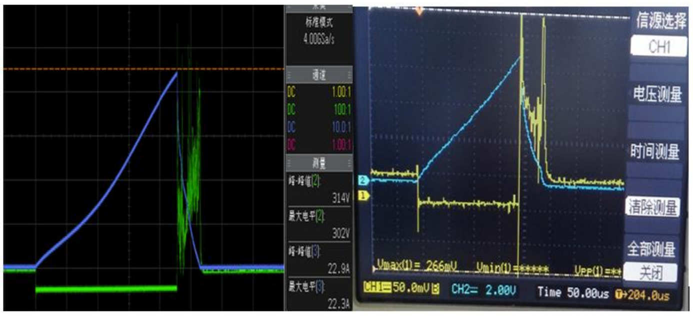


(a) (b)

Figure 3. The photo of VAT(a: co-axial type, b: ring-geometry)

The energy storage mode is induced, in circuit is an inductor. Figure 1 is the configuration of PPU. Beginning, the power V1 will charge to the capacitance, after that, open switch U1, at the same time close U2 and open IGBT V2, after that, the capacitance will charge for the inductor L, the IGBT V2 must be off when the charging end. At last, the arcing discharge between the cathode and anode will happen when open the switch U3, and one ignition is end.

The number of ignition is over to 1milllion.Figure 4 is the Typical arc pulse waveforms. Figure 4 indicate that the specific impulse is over to 1000s, and efficient reach to 13%. The VAT electric propulsion system will perform station keeping mission for the XX-1 microsatellite that developed by the academy of TIAYI in China.



(a) (b)

Figure 4. Typical arc pulse waveforms when VAT operation

B. The 5W class LPPT

The 5W class PPT developed by LIP is called μ-PPT. Figure 5 is the configuration of PPT electric propulsion system and thruster head. The PPT head is a rectangular geometry Teflon propellant[4].

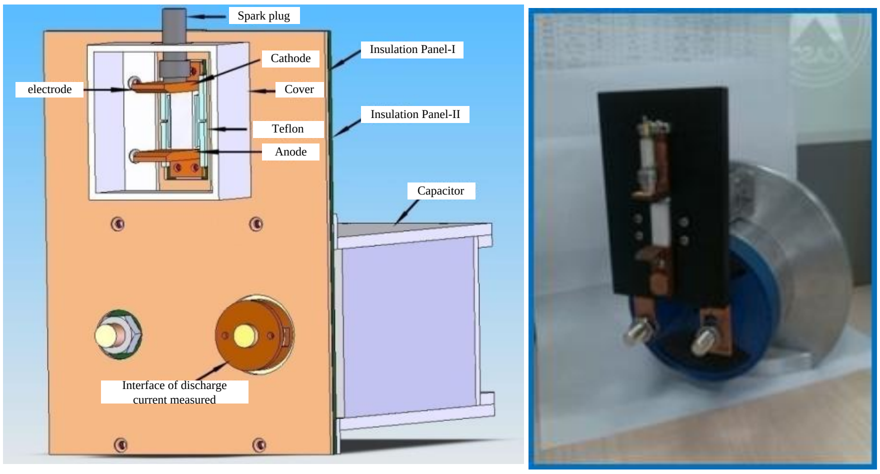


Figure 5. the configuration of PPT electric propulsion system and thruster head

The PPT was operated in a φ600mm×1000mm vacuum chamber. The vacuum is better than 10^{-4}Pa. The PPT experiment prototype is shown in Figure 5.The evolutionary process of the discharge is figure 6, the figure indicated that the breakdown start at cathode surface which besides the spark plug, then the breakdown will extend to the main discharge region, the region close to the anode, the discharge is not fill in the discharge chamber.

Figure 7 presents the changing of discharge current with about 13μs discharge time. The main discharge current peak is 22.5kA.The PPT system life test was ignited 220 million cycles. Measurement results show that the PPT discharge process has a good stability and repeatability. The performance was computed by the experiment parameter. The impulse bit is 40μN.s, the specific impulse is bigger than 700s at frequency 1Hz and discharge voltage 1600V.

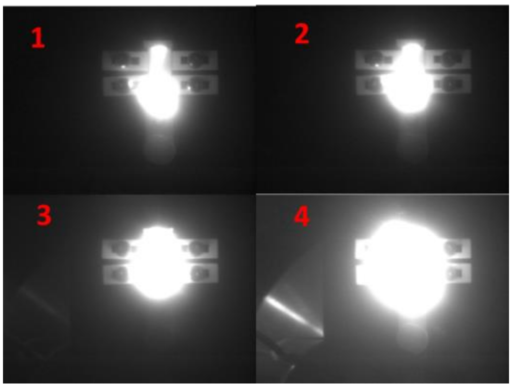


Figure 6. the evolutionary process of discharge

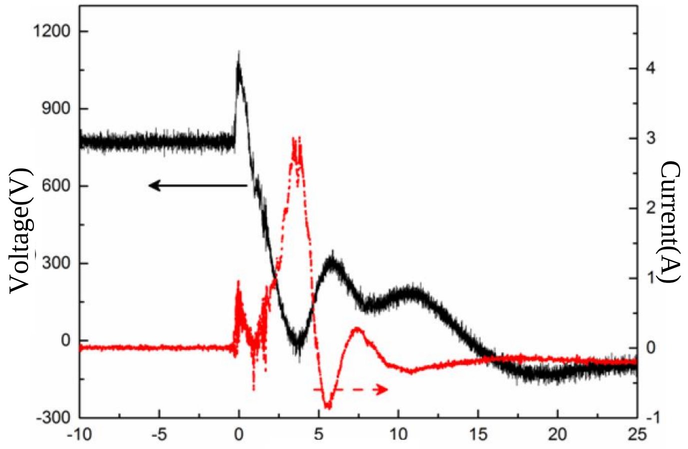


Figure 7. the main discharge current and voltage curve

The PPT system will use on the cube satellite design by Northwestern Polytechnic University. The system mass is less than 2kg, input power is less than 5W, mean thrust is larger than 40 μN, and the specific impulse larger than 700s.Figure 8 is the PPT system for the AX-3 cube satellite.

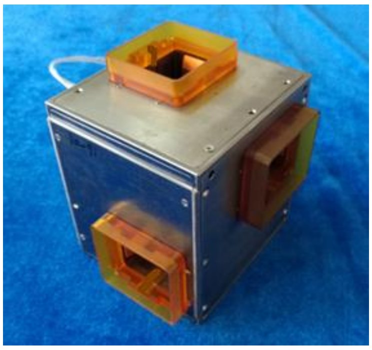


Figure 8. The PPT system for cube satellite

C. The 50W class LRIT

In order to satisfy the application of small satellite, 50W LRIT-40 was developed by LIP. The prototype was has been assembly, illustrated in figure 8. The structure has been simplification as a result of the application of inductive self-consistent discharge. An RF ion thruster usually consists of an axisymmetric, cylindrical or conical discharge chamber made of dielectric material. A helical coil, energized at low MHz radio frequency, is used to generate and sustain the plasma discharge. The LRIT-40 was equipped with two grids.

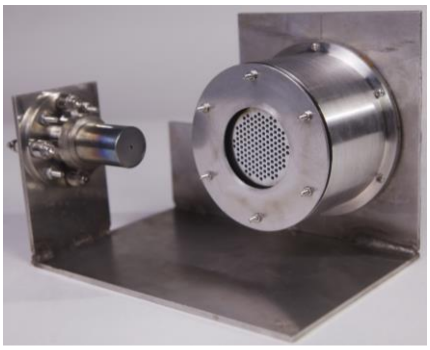


Figure 9. The prototype of LRIT-40

The diameter of ion beam is 40mm, and the performance of design is, input power 50-150W, specific impulse 2600s, trust 1-2mN. The prototype performance experiment will be tested at the end of 2017.

D. The 150W class LECR

Following DC and RF discharge technologies, microwave discharge in now considered as the third principle which can comprise an ion thruster system [5]. The LECR-50 is an 50mm diameter ion beam ion thruster. The LECR is design for small satellite that less than 300kg. The prototype was tested in TS-6S vacuum equipment. The ion beam is 38mA when input microwave power achieved to 48W, and the reflected power is 9.5W. The performance parameter was computed is 2.3 mN, 4010s.

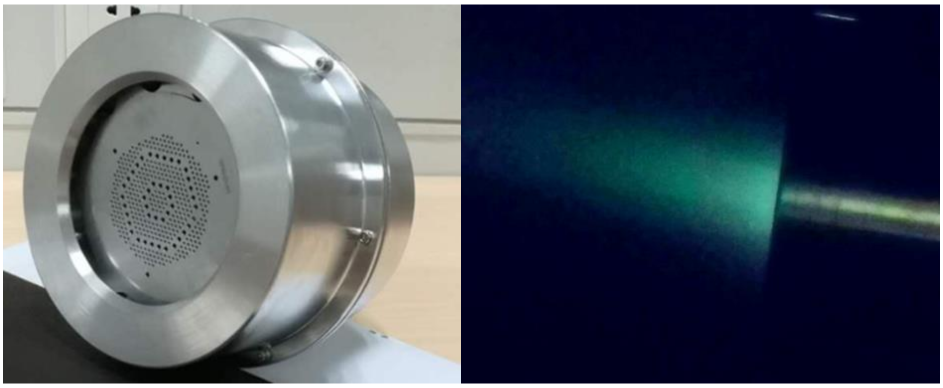


Figure 10. LECR microwave assisted discharge ion thruster

III. Conclusion

In order to increase the small and micro satellites control accuracy and lifetime, some kinds of miniaturization electric propulsion were developed by LIP. At present, LVAT and LPPT were application on the XX-1 and AX-3 cube satellite, and the tackle problems in key technology was continuance.

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