Magnetically-Enhanced Vacuum Arc Microthruster for Small Satellite Control

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Principal of operation

New type of micro-cathode thruster (µCT) is considered. The thruster utilizes magnetically enhanced vacuum arc between tubular solid anode and cathode separated by isolator as shown in Figure 1. The operation of the µCT relies on the natural expansion of arc plasma jet in vacuum. As a result of self-consistent ambipolar electric field in the expanded plasma, ions are accelerated in plasma jet up to \(10^4 - 3 \times 10^6\) m/s. An applied magnetic field works to transform radial cathode-jet flow into axial flow as shown in Figure 1. The arc spot is developed at the boundary between the metallic cathode and ceramic spacer ring. Multiple spots are exist with current per spot of about 10-30 A dependent on cathode material. Magnetic field leads to cathode spot motion in the azimuthal direction well-known as - JxB thus causing uniform cathode erosion. In the considered configuration the cathode spots are attached at the cathode-spacer interface leading to the cathode edge erosion near that interface.

Power Processing Unit

Plasma source uses the inductive energy storage for the Power Process Unit (PPU). The equivalent circuit is shown in Figure 2. (center figure). PPU is based on generation of high voltage pulse (of about 100 \( \mu\)J) at fast break of circuit containing inductor. Utilization of this PPU allows arc initiating without a need in external high voltage source for breakdown.

Guiding of plasma by magnetic field

To measure the spatial distribution of output ion current, special assembly of concentric circles plan probe was used to measure the ion current distribution outside the thruster channel. Figure 5 is showing the spatial evolution of the ion current distribution outside the source channel with different magnetic field strength. The concentric circles plan probe was biased -30V with respect to the cathode. As shown in Figure 5, it is shown that plasma generated at the cathode spot is guided along the magnetic field line. And different magnetic strength has the different ability the guide the plasma.

Figure 1. (a) Micro-Vacuum Arc thruster (without magnetic coil here), (b) Schematic of the µCT.

Figure 2. Temporal evolution of anode-cathode voltage and inductor current. Inset shows the equivalent circuit of an inductive energy storage Power Process Unit.

Figure 3. (a) Temporal evolution of a signal from 4-probe assembly indicating rotation of the cathode spot. (b) Magnetic field simulated numerically using FEMM Software.

Figure 4. Temporal evolution of the radial distribution of ion current at the distance of about 7.6 cm from the source exit.(a) Schematic of assemble 12 probe setup, (b) Without magnetic field, (c) With magnetic field, of about 0.3 T.

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