Pulsed Plasma Thruster Ignitor Plug Ignition Characteristics

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Abstract

A SEMICONDUCTOR spark gap ignitor plug used to initiate the discharge in a pulsed plasma thruster has been investigated experimentally. Among the parameters studied were dynamic plug impedance, energy utilization efficiency, erosion characteristics, and plume velocity. This work was directed toward improvement of ignitor plug performance in the pulsed plasma thruster.

Contents

The ignitor plug, shown in Fig. 1, consists of two coaxial electrodes separated by insulating material. At the face of the plug, this insulating material is covered with a thin semiconductor layer approximately 0.5 mm thick. When a sufficient voltage is applied across the electrodes of the plug, an arc occurs ablating material from a point on the semiconductor ring and creating a small highly ionized plasma puff. In the pulsed plasma thruster (PPT) this plug plasma initiates an arc breakdown between the thruster's rail-type anode and cathode electrodes (Fig. 2). A more complete description of the thruster and its potential applications is given by Palumbo.[1]

The tests were run with the plug isolated in a vacuum bell jar with current and voltage probes monitoring the electrical characteristics of the plug. The dynamic impedance of the plug plasma was determined from the voltage and current traces, as was the total discharge energy. Figure 3 shows the resulting waveforms for a typical plug discharge. Energy conversion efficiencies were generally low, as is common in plasma jet ignitor plugs of this type.[2] It is thought that the low efficiency is due to an impedance mismatch between the plug and the trigger circuit used to fire it. An average value of the plug impedance, which varies from about 0.5-0.1 Ω, was found to be approximately 0.2 Ω.

In the course of analyzing the voltage and current data it was observed that the plug operates in two modes. For a fast-rising voltage pulse breakdown was observed to occur on the rising edge of the pulse, whereas for slower rising pulses breakdown occurred after the voltage peak. It was also noticed that for the first case (a short voltage risetime) the breakdown voltage decreased in a manner inversely proportional to the energy supplied to the plug. Data were examined both for the ignitor plug firing in air at 1 atm and in a vacuum of about 10^{-5} Torr. Two major differences were observed in the two sets of data. First, as would be expected, higher voltages were required to cause breakdown in air rather than in a vacuum. Second, the air data followed the previously stated proportionality over the entire range of energies possible for the triggering circuit being used. However, under vacuum the performance of the plug underwent a transition at an energy of 0.2 J, where the breakdown voltage began to decrease with decreasing voltage slew rate. This effect is shown in Fig. 4.

Erosion products collected from the plug discharge were analyzed to determine information about plug breakdown. The results indicated that the primary erosion products were derived from the semiconductor and cathode rings. This agrees with visual observations of the ignitor plug discharge and with electron micrographs taken of the eroded plug face. Velocity measurements were attempted using two simple spark gap probes. These data showed a great deal of scatter which increased with a decrease in the supplied energy. The spark gap probe measurements did give a rough idea of the plasma plume velocity. For a supplied energy of 0.16 J the values ranged from about 6-25 km/s and from 11-23 km/s for a supplied energy of 0.64 J. The average values showed an increasing trend with energy; however, considering the quality of the data it is impossible to make any assumptions from this.

The thrust of these experiments was toward improved performance of the ignitor plug in the pulsed plasma thruster. However, it is felt that this ignitor plug has application as a means of initiating other plasma arcs.

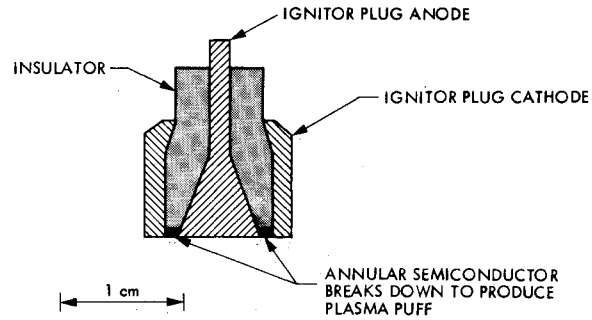

Fig. 1 Ignitor plug cross section.

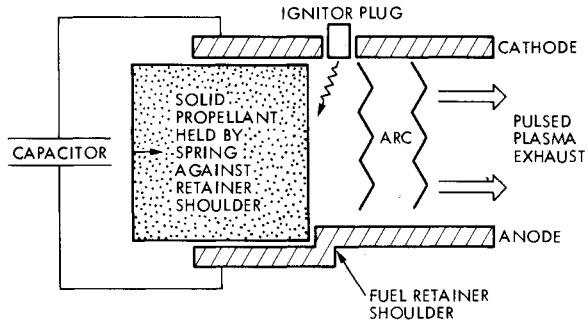

Fig. 2 Solid propellant pulsed plasma thruster concept.

Presented as Paper 82-0924 at the AIAA/ASME Third Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982; submitted June 7, 1982; synoptic received Feb. 28, 1983. This paper is declared a work of the U.S. Government and therefore is in the public domain. Full paper available from AIAA Library, 555 W. 57th St., New York, N.Y., 10019; microfiche—$4.00, hard copy—$8.00. **Remittance must accompany order.**

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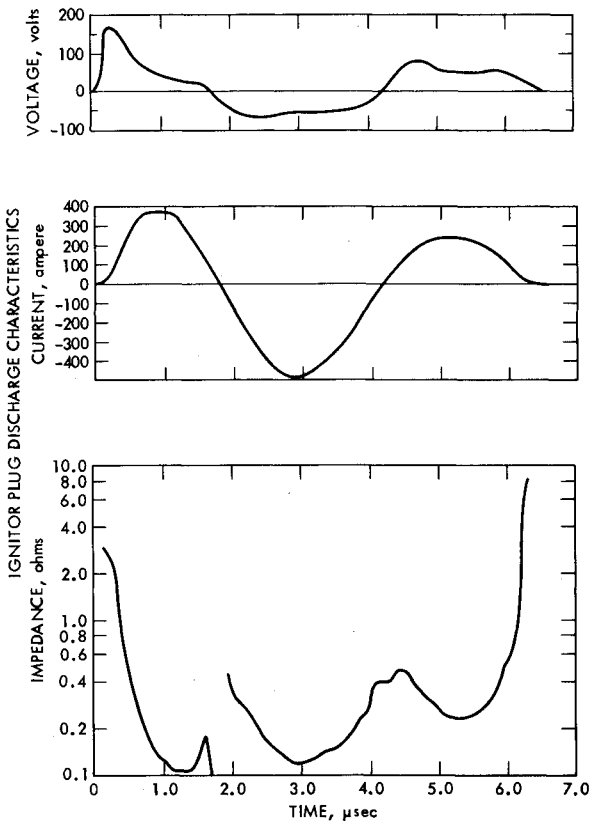

Fig. 3 Typical plug discharge impedance variations.

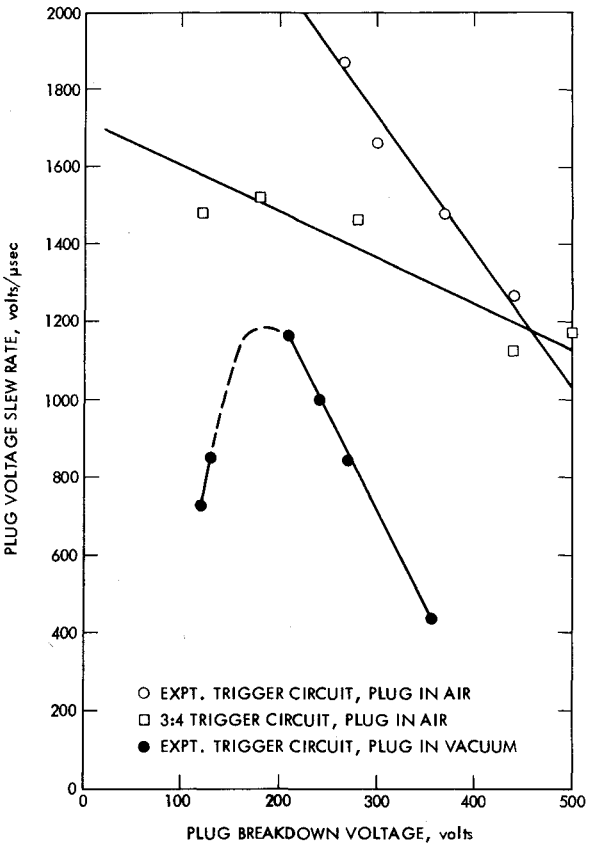

Fig. 4 Correlation of plug voltage slew rate to breakdown.

Acknowledgments

The research described herein was performed at the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the Air Force Rocket Propulsion Laboratory under Contract F0411-80-X-0041, through an agreement with the National Aeronautics and Space Administration.

References

[1]Palumbo, D.J., "Solid Propellant Pulsed Plasma Propulsion System Development for N-S Stationkeeping," AIAA Paper 79-2097, Oct. 1979.

[2]Clements, R.M., Smy, P.R., and Dale, J.D, "An Experimental Study of the Ejection Mechanism for Typical Plasma Jet Igniters," *Combustion and Flame,* Vol. 42, 1981, pp. 287-295.