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NASA Case ~~No.~~ LEW 10,814-1

GEShook:jm

APPLICATION FOR LETTERS PATENT

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT Shigeo Nakanishi

a citizen of the United States of America, employee of the U.S. Government

and resident of Berea, Ohio

has invented certain new and useful improvements in ION THRUSTER CATHODE

of which the following is a specification:

ABSTRACT OF THE DISCLOSURE

An encapsulated heater forms a hollow body for a cathode used in an ion thruster. A radiation shield surrounds the heater and supports an end cap.

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention is concerned with an improved cathode or electron emitter for an electrostatic ion thruster. The invention is particularly directed to providing a compact cathode that is both reliable and durable for use in a small electrostatic ion thruster.

Electrostatic ion thrusters of the type shown in U.S. Patent No. 3,156,090 utilize cathodes or electron emitters to provide electrons for ionizing a propellant, such as mercury vapor. Hollow cathodes have been proposed for these thrusters. One such cathode is shown in copending application serial No. 804,172 which was filed March 4, 1969. In this cathode mercury vapor is fed to a hollow tube having a small aperture in the closed end. A mercury arc is established by applying a high potential between the cathode and a keeper. Once the arc has been established the discharge is sustained with only moderate voltages between the cathode and the keeper. The keeper is in the form of a ring electrode mounted concentric with respect to the cathode at a suitable gap distance. This hollow cathode and keeper are mounted on a dielectric material base, and the assembly is located concentrically within a magnetic field forming pole piece which is a component part of the thruster. Such a hollow cathode is exposed to the plasma discharge of an ion chamber and is called an open-type cathode.

Structural problems, poor durability, and undesirable performance characteristics inherent in open-type cathode are disadvantages encountered with prior art devices. By way of example, the hollow cathode and keeper electrode must be electrically isolated from each other and maintained in their correct relative position. Misalignment of these two components as well as variation in gap distance due to thermal expansion can occur. Also, the open-type cathode is exposed to plasma discharge and is subject to ion bombardment. The resulting sputtering erosion damage may reduce the usable lifetime of the cathode.

The hollow cathode must supply free electrons to the thruster ion chamber. This is accomplished by providing a seat of electrical discharge in a mercury vapor environment. While the exact mechanism of this electron emission is not clearly understood, it is believed that some threshold value of surface temperature and electrical field, particularly in the region of the cathode aperture, is required along with the necessary number density of mercury vapor atoms. The open-type cathode requires heat shielding to avoid excessive applied heating power, particularly during the initiation of the cathode discharge, because of the large amount of exposed hot surface where heat can be lost by radiation. Also, a limiting value of propellant flow rate exists below which the open-type hollow cathode ceases to operate. This is attributed to the reduced number density of mercury atoms in the cathode-keeper region, and stable operation under throttled conditions of propellant flow may not be possible.

SUMMARY OF THE INVENTION

A cathode constructed in accordance with the present invention has a tube mounted in an encapsulated heater. A high purity alumina tube surrounds the heater in concentric relationship. This tube serves both as a radiation shield and as an insulated holder for a tantalum keeper cap. The enclosure helps to maintain the required mercury atom number density in the cathode keeper region at low propellant flow rates.

OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to provide a cathode that is compact, reliable, and durable for use in a small electrostatic ion thruster.

Another object of the invention is to provide a hollow cathode which maintains the required dimensional tolerances for use in an electrostatic ion thruster.

A further object of the invention is to provide a hollow cathode that maintains the required mercury atom number density in the keeper region at low propellant flow rates.

These and other objects of the invention will be apparent from the specification which follows and from the drawing wherein like numbers are used throughout to identify like parts.

DESCRIPTION OF THE DRAWING

The drawing is an enlarged axial section view of a hollow cathode constructed in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A hollow cathode constructed in accordance with the present invention has a tubular member 10 as shown in the drawing. The tube 10 is of an electrically conducting material such as tantalum. It is connected to a source of propellant, such as mercury vapor. The tube 10 has a small diameter. By way of illustration, tubes having outside diameters between 0.08 inches and 0.13 inches have been satisfactory.

One end of the tube 10 which is to be mounted within the ion thruster is inserted into a wire coil 12. Tungsten-rhenium wire having a diameter of about 10 mils has been satisfactory for the coil 12. The wire forms a resistance heater when a current is passed through the coil 12.

One end of the coiled wire is connected at 14 to the electrically conducting tube 10. The opposite end of the resistance heater wire forming the coil 12 has a straight portion 16 in substantial juxtaposition with the tube 10. The end of the straight portion 16 is connected to an electrical lead wire 18 through a connector 20.

After the tube 10 has been inserted into the coil 12 and the end of the heater wire has been connected at 14, a layer of insulating material 22 is applied to the adjacent surface of the tube 10 as well as the wire forming the coil 12. Also the straight portion 16 is separated from the tube 10 by the insulating material 22. A layer of flame-sprayed alumina has been satisfactory for the layer of insulating material 22.

The end of the tube 10 having the heating coil 12 mounted thereon is then inserted into a tube 24 of solid alumina. Tubes having diameters between 0.25 inches and 0.30 inches have been satisfactory for this purpose. After the tube 10 is properly positioned in the alumina tube 24 a suitable adhesive material 26, such as a high temperature ceramic cement, is forced under pressure through a hole in the sidewall of the alumina tube 24.

A shadow shield 28 is mounted on the extreme outermost end of the tube 10 outwardly of the heater 12. This shadow shield 28 is of a suitable material, such as tantalum, and protects the heater from sputtering damage as well as undesirable coating of sputtered material upon the insulating surfaces.

An electrode in the form of a tantalum keeper cap 30 is mounted on the end of the alumina tube 24. An electrical lead 32 is connected to the keeper cap 30. The lead 32 is mounted on the outermost surface of the alumina tube 24. A suitable aperture 34 is formed in the center of the keeper cap to facilitate passage of the mercury vapor upon the initiation of an arc between the tube 10 and the keeper cap 30.

In operation, a current is passed through the coil 12 to heat the end of the tube 10. A propellant vapor flows through the tube 10 to a small aperture 36 which is in alignment with the aperture 34 in the keeper cap 30.

A potential of about 300 volts is applied between the keeper cap 30 and the tube 10. Electrons emitted from the heated tube 10 initiate an arc discharge. The plasma formed by this discharge reduces the negative space charge which builds up at the cathode surface thereby enabling electrons to be discharged from the cathode through the aperture 34 into the thruster ion chamber.

Table I illustrates the capability of an enclosed cathode constructed in accordance with the invention to maintain a stable discharge at very low propellant flow rates and heating power levels. It will be appreciated that various structural modifications may be made to the disclosed cathode without departing from the spirit of the invention or the scope of the subjoined claims.

TABLE I: KEEPER VOLTAGES AT VARIOUS NEUTRAL FLOW EQUIVALENTS OF Hg^+

Neutral Flow Equivalent of Mercury	CATHODE TYPE	
	OPEN	ENCLOSED
20 MA	24 Volts	22.0 Volts
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10 MA	No operation	22.5 Volts
6 MA	No operation	23.5 Volts
4 MA	No operation	27 Volts
2 MA	No operation	34.5 Volts

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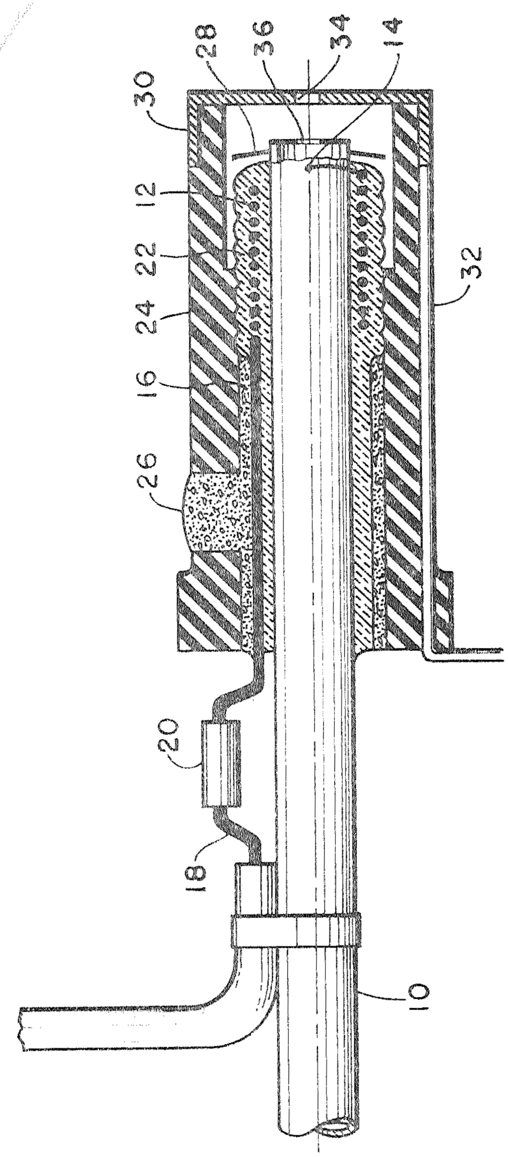

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United States Patent

[11] 3,603,088

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[21] Appl. No. 38,262
[22] Filed May 18, 1970
[45] Patented Sept. 7, 1971
[73] Assignee The United States of America as represented by the Administrator of the National Aeronautics and Space Adminsitration

[54] **ION THRUSTER CATHODE**
10 Claims, 1 Drawing Fig.

[52] U.S. Cl. 60/202, 313/231
[51] Int. Cl. F03h 1/00
[50] Field of Search 60/202, 203; 315/111; 313/231; 417/48, 51

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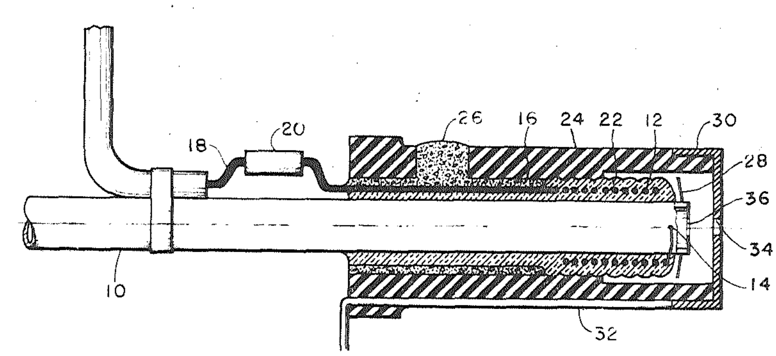

ION THRUSTER CATHODE

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In operation, a current is passed through the coil 12 to heat the end of the tube 10. A propellant vapor flows through the tube 10 to a small aperture 36 which is in alignment with the aperture 34 in the keeper cap 30.

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Table I illustrates the capability of an enclosed cathode constructed in accordance with the invention to maintain a stable discharge at very low propellant flow rates and heating power levels. It will be appreciated that various structural modifications may be made to the disclosed cathode without departing from the spirit of the invention of the scope of the subjoined claims.

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4 ma.	No operation	27 Volts
2 ma.	No operation	34.5 Volts

What is claimed is:

1. An enclosed cathode for an ion thruster comprising

an electrically conducting tubular member for directing propellant flow into the ion thruster,

means for heating an end portion of said tubular member,

insulating means covering said heating means and said tubular member,

an electrode mounted on the end of said insulating means adjacent said heating means, said electrode and said insulating means forming an enclosure about the extreme outermost end portion of said tubular member adjacent said heating means to maintain a predetermined propellant atom number density adjacent said outermost end portion at low propellant flow rates, and

means for initiating an arc between said tubular member and said electrode.

2. An enclosed cathode as claimed in claim 1 including means in the enclosure about the extreme outermost end portion of the tubular member for protecting the heating means from sputtering and coating damages.

3. An enclosed cathode as claimed in claim 1 including a tantalum tube fir directing mercury vapor into the ion thruster.

4. An enclosed cathode as claimed in claim wherein the means for heating the end portion of the tubular member comprises a wire coil forming a resistance heater.

5. An enclosed cathode as claimed in claim 4 wherein one end of the wire coil is connected to an electrical lead wire and the opposite end is connected to said electrically conducting tubular member.

6. An enclosed cathode as claimed in claim 5 including a layer of flame sprayed alumina over said wire coil and said electrically conducting tubular member.

7. An enclosed cathode as claimed in claim 1 including a tube of alumina surrounding the heating means and the electrically conducting tubular member to provide a radiation shield and support for the electrode.

8. An enclosed cathode as claimed in claim 7 including adhesive means for securing said alumina tube to said heating means and said electrically conducting tubular member.

9. An enclosed cathode as claimed in claim 7 including an electrode mounted in the alumina tube adjacent the outermost end portion of said electrically conducting tube, said electrode being rigidly secured to said alumina tube to maintain alignment and a predetermined spacing between said electrode and the end of said electrically conducting tube.

10. An enclosed cathode as claimed in claim 9 wherein the electrode comprises a tantalum cap having an aperture therein.