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The Director

of the United States Patent and Trademark Office has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this United States

Patent

grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America, and if the invention is a process, of the right to exclude others from using, offering for sale or selling throughout the United States of America, products made by that process, for the term set forth in 35 U.S.C. 154(a)(2) or (c)(1), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b). See the Maintenance Fee Notice on the inside of the cover.

Katherine Kelly Vidal

Director of the United States Patent and Trademark Office

Maintenance Fee Notice

If the application for this patent was filed on or after December 12, 1980, maintenance fees are due three years and six months, seven years and six months, and eleven years and six months after the date of this grant, or within a grace period of six months thereafter upon payment of a surcharge as provided by law. The amount, number and timing of the maintenance fees required may be changed by law or regulation. Unless payment of the applicable maintenance fee is received in the United States Patent and Trademark Office on or before the date the fee is due or within a grace period of six months thereafter, the patent will expire as of the end of such grace period.

Patent Term Notice

If the application for this patent was filed on or after June 8, 1995, the term of this patent begins on the date on which this patent issues and ends twenty years from the filing date of the application or, if the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121, 365(c), or 386(c), twenty years from the filing date of the earliest such application ("the twenty-year term"), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b), and any extension as provided by 35 U.S.C. 154(b) or 156 or any disclaimer under 35 U.S.C. 253.

If this application was filed prior to June 8, 1995, the term of this patent begins on the date on which this patent issues and ends on the later of seventeen years from the date of the grant of this patent or the twenty-year term set forth above for patents resulting from applications filed on or after June 8, 1995, subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b) and any extension as provided by 35 U.S.C. 156 or any disclaimer under 35 U.S.C. 253.

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(12) **United States Patent**
Li et al.

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(54) **VACUUM CATHODE ARC-INDUCED PULSED THRUSTER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 114 days.

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(52) **U.S. Cl.**
CPC ***F03H 1/0087*** (2013.01)

(58) **Field of Classification Search**
CPC F03H 1/0087
See application file for complete search history.

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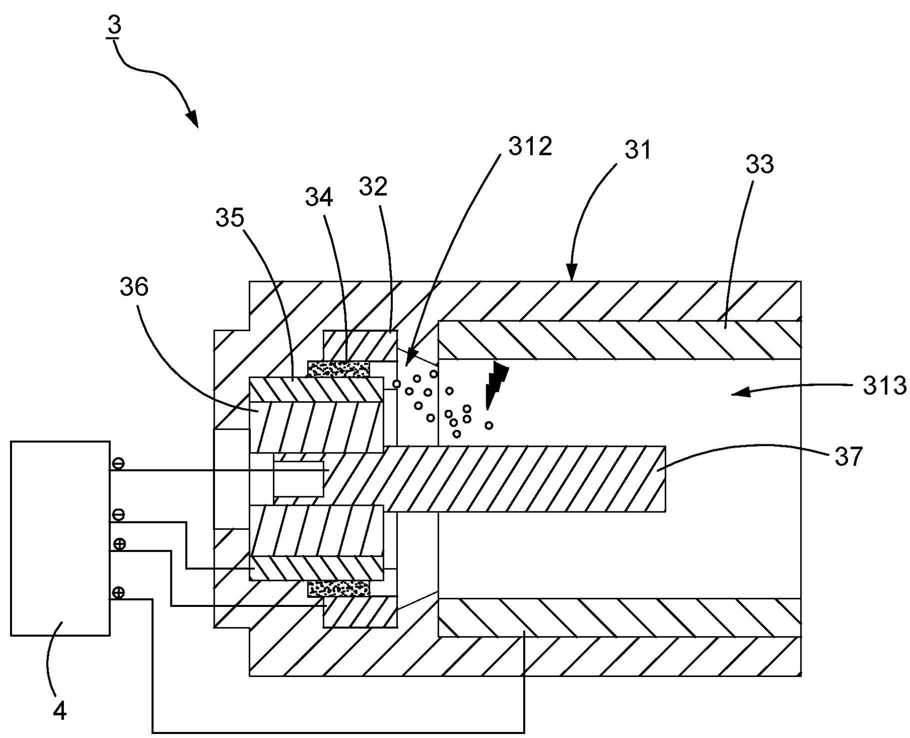
(57) **ABSTRACT**

A vacuum cathode arc-induced pulsed thruster includes a housing where a triggering room and an electric discharging room are defined and are in communication with each other, a first anode unit and a first cathode unit concentrically disposed in the triggering room, a second anode unit disposed in the electric discharging room, an insulating fuel layer concentrically located between the first anode unit and the first cathode unit, a main insulating layer concentrically surrounded by the first cathode unit, and a second cathode unit inserted from the triggering room into the electric discharging room. Thus, the vacuum cathode arc-induced pulse thruster is lightweight and has low manufacturing costs, low system complexity, and less energy consumption. Carbon deposition caused during an electric discharging process is prevented from affecting an inducing effect to thereby prolong the service life of the thruster and increase the control precision and inducing precision effectively.

5 Claims, 6 Drawing Sheets



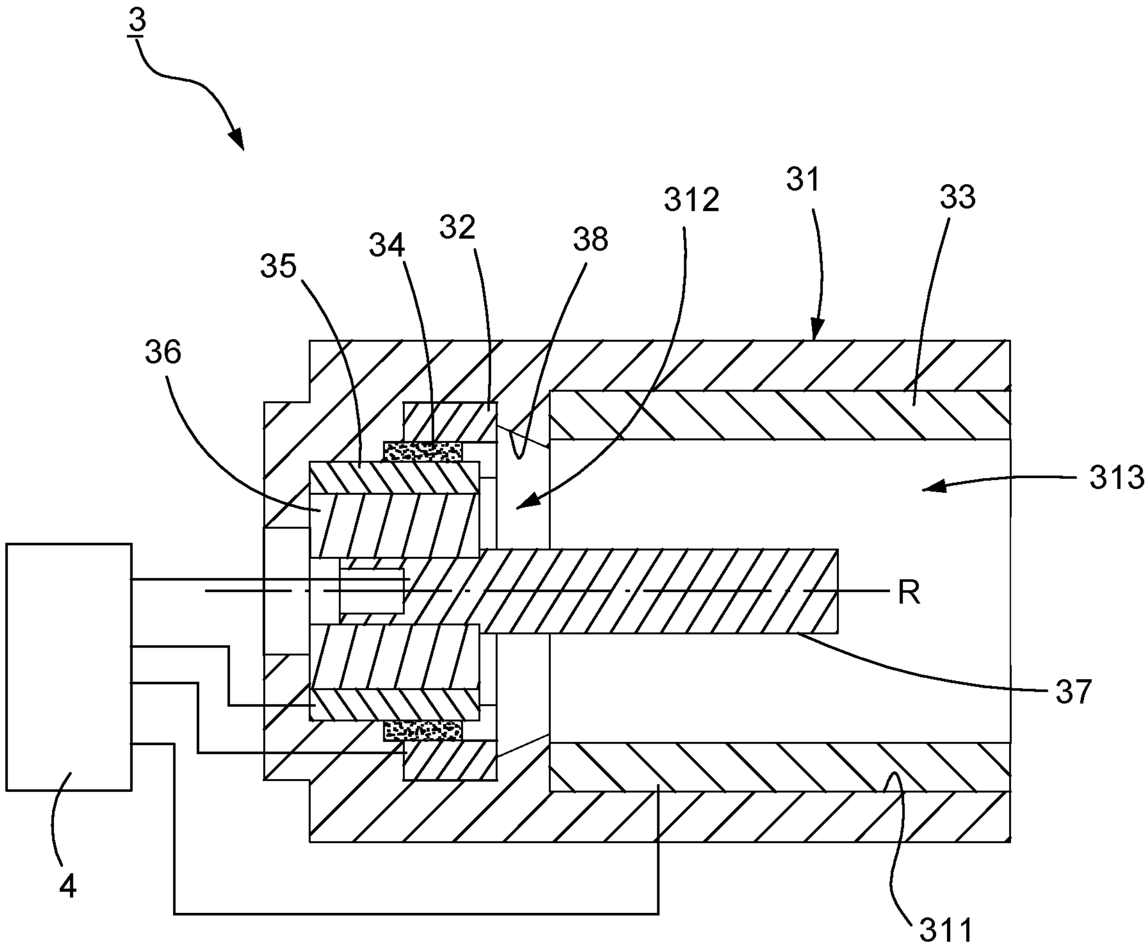


FIG. 1

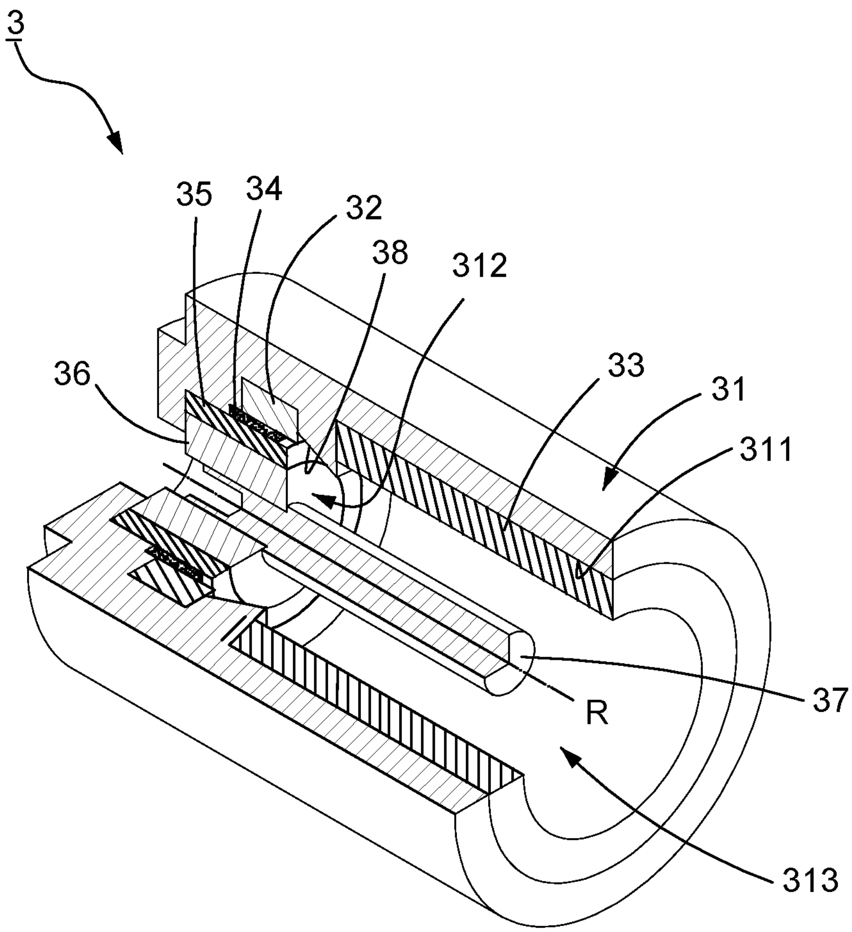


FIG. 2

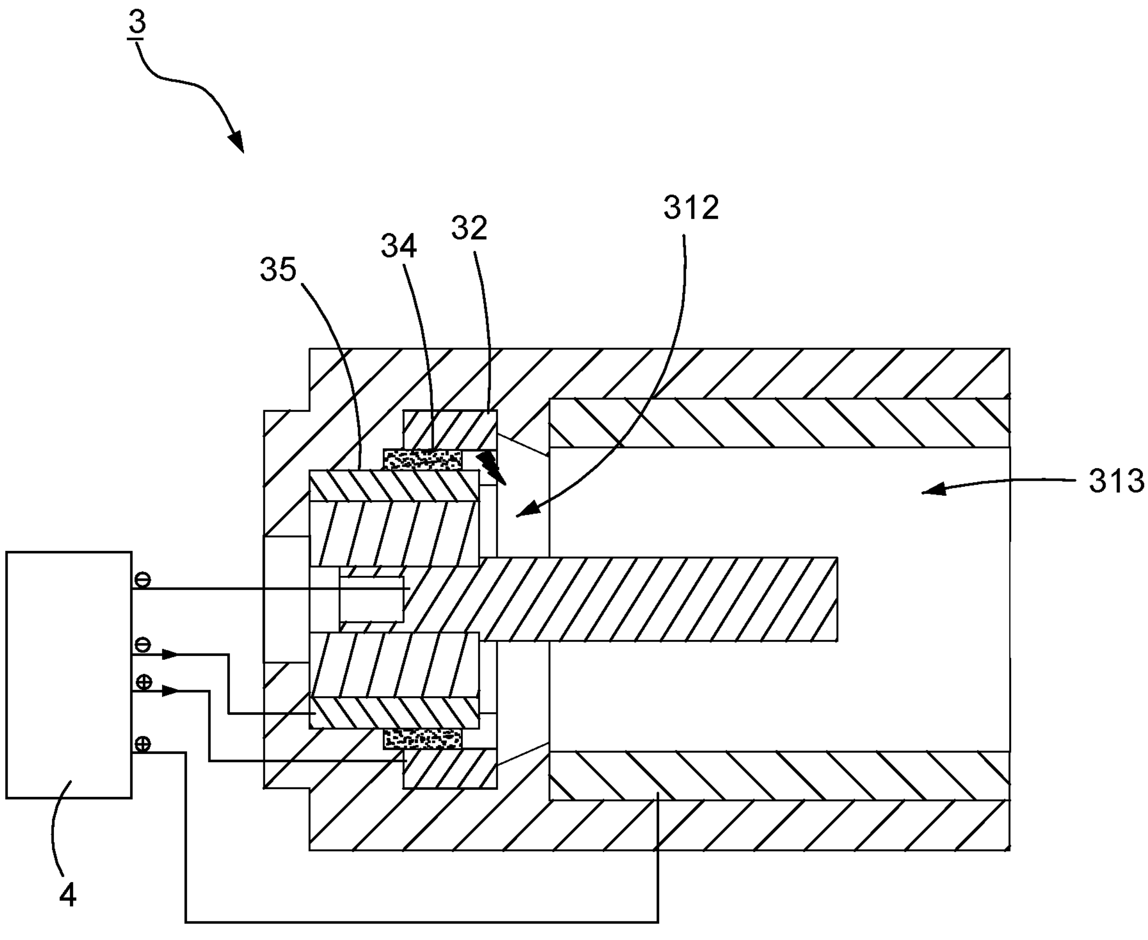


FIG. 3

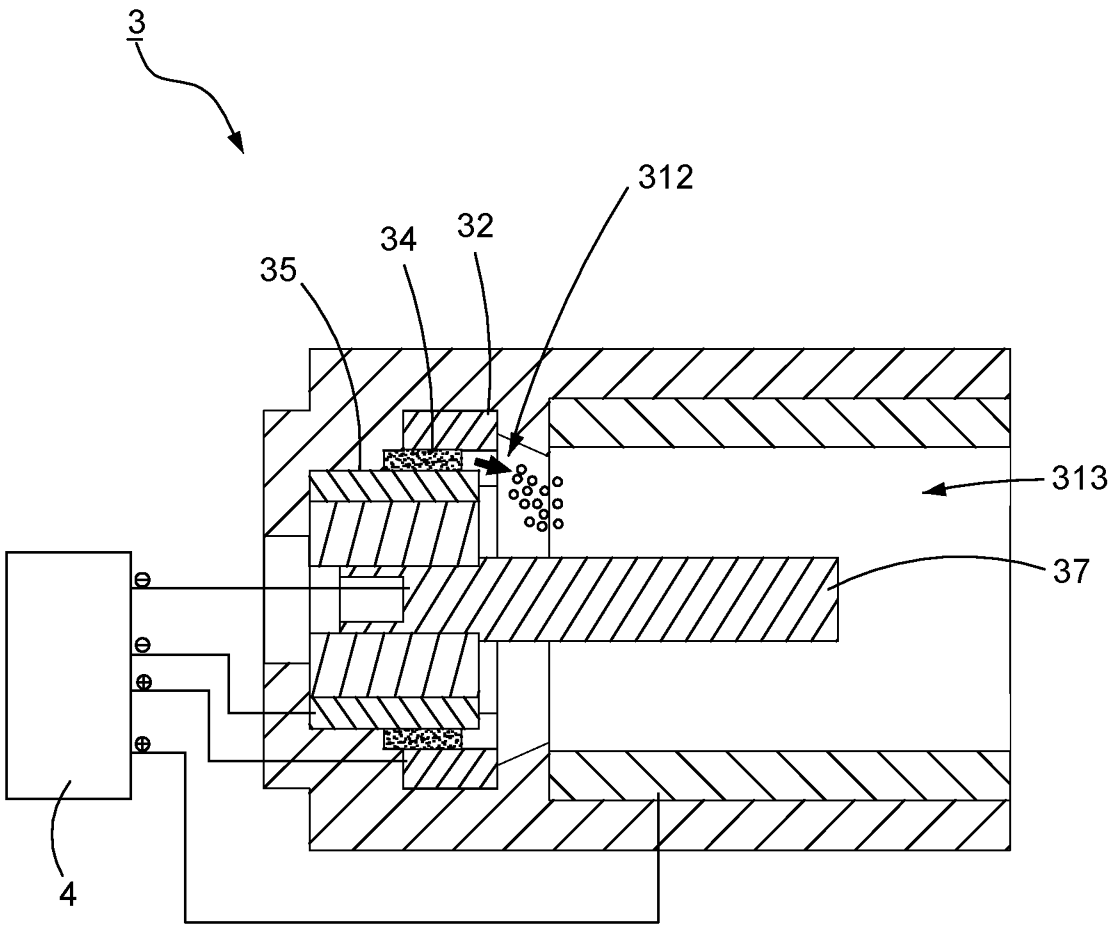


FIG. 4

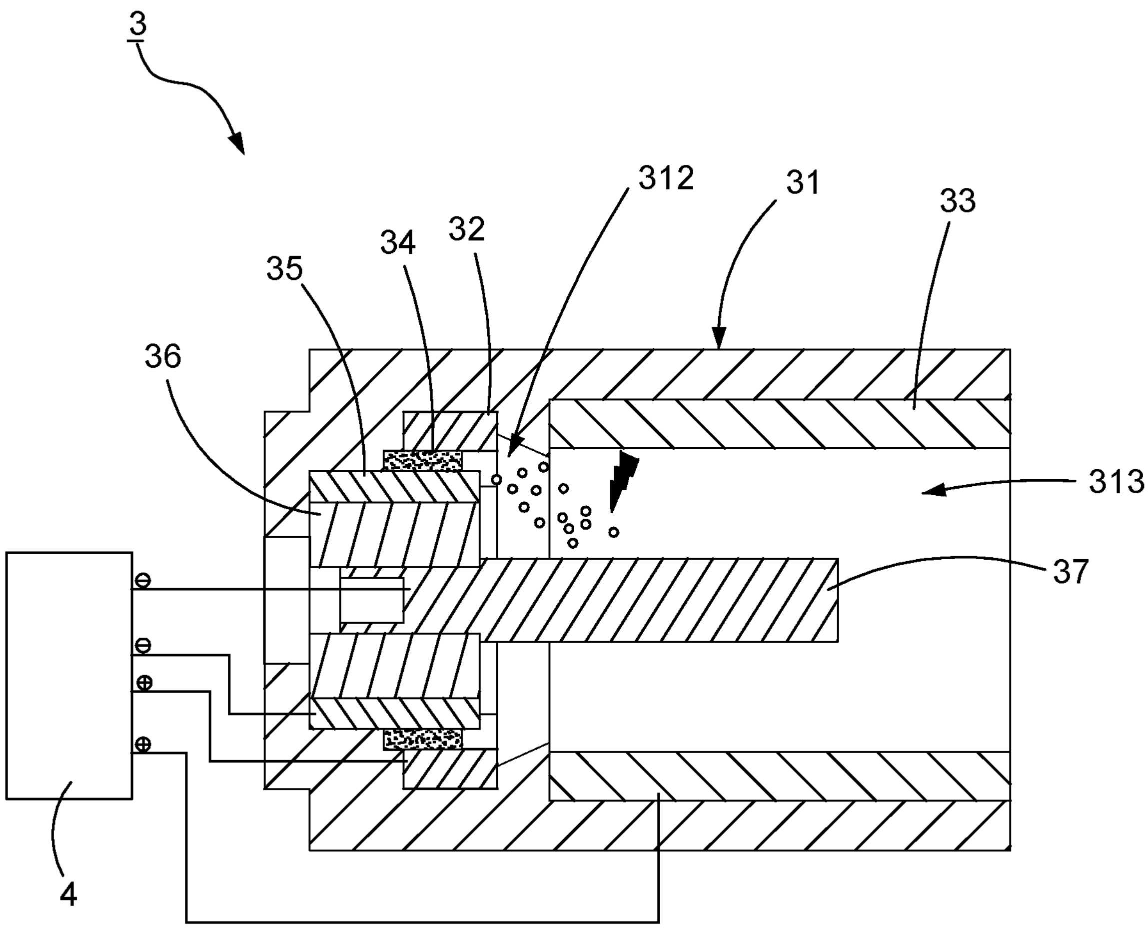


FIG. 5

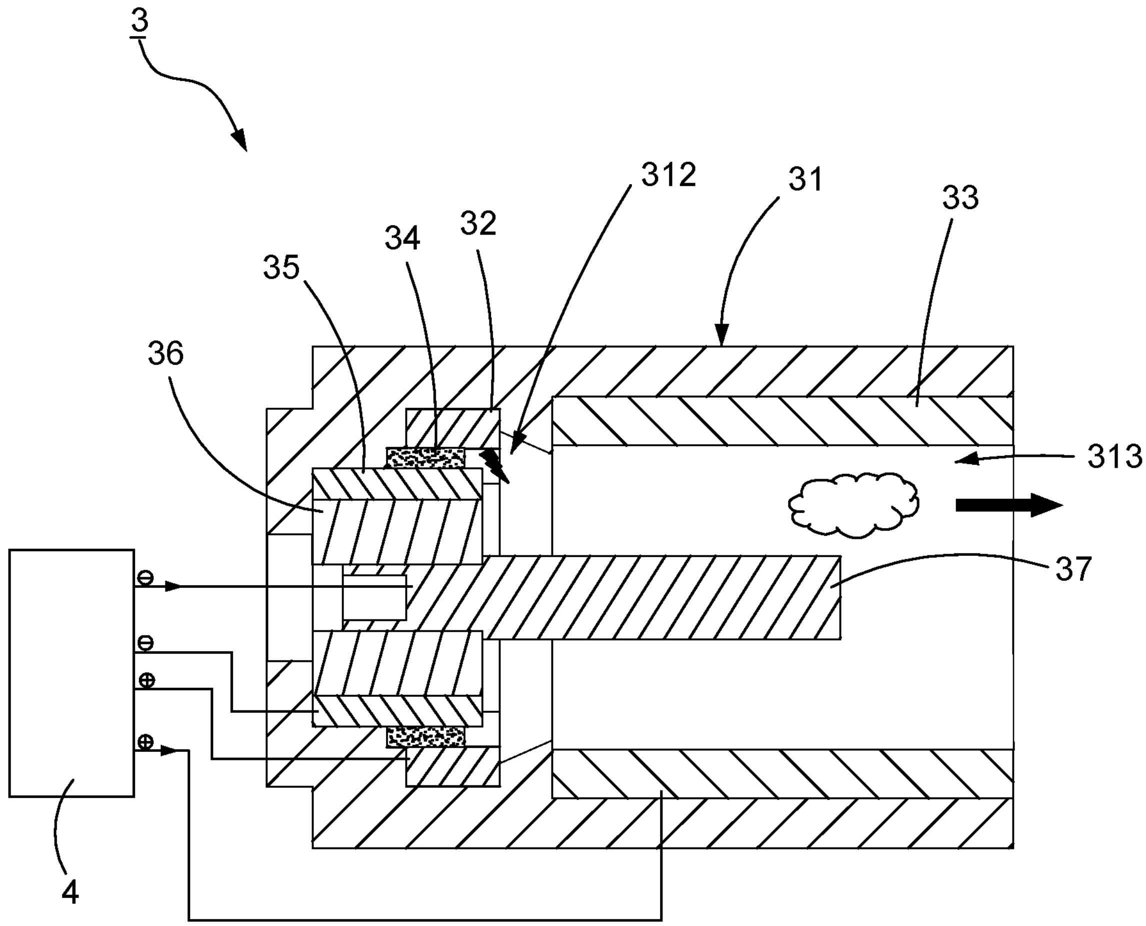


FIG. 6

VACUUM CATHODE ARC-INDUCED PULSED THRUSTER

BACKGROUND OF THIS INVENTION

1. Field of this Invention

This invention relates to a thruster and relates particularly to a vacuum cathode arc-induced pulsed thruster.

2. Description of the Related Art

Pulsed plasma thruster (PPT) is a new type of thruster developed in recent years. The pulsed plasma thruster is an electric propulsive thruster which accelerates the plasma by an interaction between electric field and magnetic field to create thrust. The pulsed plasma thruster is one of the most promising electric propulsive thrusters since it is lightweight and has low manufacturing costs, simple structure, and less energy consumption. Meanwhile, it can achieve a preferable effect in attitude control and station keeping for satellites. Two different prototypes of general pulsed plasma thruster are developed. One is solid fed pulsed plasma thruster. The solid fed pulsed plasma thruster has simple structure and is the most commonly used thruster. It induces the electric discharge and further creates thrust by electrodes of spark plug and propellant. However, in order to fit the requirements of inducing the electric discharge by the spark plug, extremely high voltage is needed under a vacuum environment. Further, carbon generated during an electric discharge process will deposit on surfaces of the electrodes of the spark plug and the propellant, and that will affect the electric discharge and inducing effect. Further, the service life is shortened and use efficiency is reduced greatly.

The other one is gas initiated pulsed plasma thruster. For the gas initiated pulsed plasma thruster, capacitance can cause the electric discharge when enough capacitive gas is generated between electrodes, and argon is used as both propellant and initiator for inducing the electric discharge. The capacitive gas is adapted to execute the electric discharge. When the breakdown voltage is smaller than the breakdown voltage of the atmospheric environment, the impulse generated by the maximum single pulse can achieve the effect of propulsion. However, gas propellant will consume more fuel and the propulsive efficiency is poor. Moreover, both solid fed pulsed plasma thruster and gas initiated pulsed plasma thruster will cause late-time ablation, and that will reduce the performance and service life of the thruster. Accordingly, it is an issue how to develop a thruster which has longer service life, higher performance, and lower energy consumption.

SUMMARY OF THIS INVENTION

The object of this invention is to provide a vacuum cathode arc-induced pulsed thruster capable of reducing influence of carbon deposition, converting carbon deposition into fuel, prolonging service life effectively, and increasing the control precision and inducing precision.

The vacuum cathode arc-induced pulsed thruster of this invention includes a housing where a triggering room and an electric discharging room are enclosed and a central axis is defined, a first anode unit disposed in the triggering room, a second anode unit disposed in the electric discharging room and spaced from the first anode unit, an insulating fuel layer surrounded by the first anode unit, a first cathode unit disposed in the triggering room and spaced from the first

anode unit to allow the insulating fuel layer to be located between the first anode unit and the first cathode unit, a main insulating layer surrounded by the first cathode unit, and a second cathode unit disposed in the housing and inserted from the triggering room into the electric discharging room along the central axis. Meanwhile, the first anode unit, the insulating fuel layer, the first cathode unit, and the main insulating layer are in concentric relationship with one another around the central axis of the housing. Therefore, after the first anode unit and the first cathode unit interact and induce the electric discharge, the insulating fuel layer located between the first anode unit and the first cathode unit is induced to generate plasma. The plasma then enters into the electric discharging room. The second anode unit and the second cathode unit further interact and induce the electric discharge to allow the high-speed exhaust velocity of metal ions in the plasma to generate thrust. Thus, no additional element such as spark plug is needed. The vacuum cathode arc-induced pulsed thruster is lightweight and has low manufacturing costs, low system complexity, and less energy consumption. Carbon deposition caused during an electric discharging process is prevented from affecting an inducing effect to thereby convert carbon deposition into fuel, prolong the service life of the thruster and increase the control precision and inducing precision effectively.

Preferably, a control device is connected to the first anode unit, the first cathode unit, the second anode unit, and the second cathode unit respectively.

Preferably, the insulating fuel layer is made of Polytetrafluoroethylene (sold under the trademark TEFLON™).

Preferably, a partitioning unit projects from the inner peripheral wall of the housing in order that the first anode unit and the second anode unit are spaced from each other.

Preferably, the partitioning unit tapers from the triggering room to the electric discharging room.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view showing a first preferred embodiment of this invention;

FIG. **2** is a perspective view showing the first preferred embodiment of this invention;

FIG. **3** is a schematic view showing the first anode unit and the first cathode unit interact and induce the electric discharge;

FIG. **4** is a schematic view showing the plasma is generated;

FIG. **5** is a schematic view showing the plasma enters into the electric discharging room from the triggering room and forms a channel; and

FIG. **6** is a schematic view showing the second anode unit and the second cathode unit interact and induce the electric discharge and generate thrust.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1** and FIG. **2**, a vacuum cathode arc-induced pulsed thruster **3** of a first preferred embodiment of this invention comprises a housing **31** defining a central axis R and having an inner peripheral wall **311** which encloses a triggering room **312** and an electric discharging room **313** respectively, a first anode unit **32** disposed in the triggering room **312** and fitting the inner peripheral wall **311** of the housing **31**, a second anode unit **33** disposed in the electric discharging room **313** and fitting the inner peripheral wall **311** of the housing **31**, an insulating fuel layer **34** surrounded by the first anode unit **32**, a first cathode unit **35** disposed in the triggering room **312** and spaced from the first anode unit **32** to allow the insulating fuel layer **34** to be located between the first anode unit **32** and the first cathode unit **35**, a main insulating layer **36** surrounded by the first cathode unit **35**, and a second cathode unit **37** disposed in the housing **31** and inserted from the triggering room **312** into the electric discharging room **313** along the central axis R. The first anode unit **32** and the second anode unit **33** are spaced from each other. The triggering room **312** and the electric discharging room **313** are in communication with each other. Further, the first anode unit **32**, the insulating fuel layer **34**, the first cathode unit **35**, and the main insulating layer **36** are in concentric relationship with one another around the central axis R of the housing **31**. In this preferred embodiment, the insulating fuel layer **34** is made of a Polytetrafluoroethylene (sold under the trademark TEFLON™).

In this preferred embodiment, a partitioning unit **38** projects from the inner peripheral wall **311** of the housing **31** so that the first anode unit **32** and the second anode unit **33** are spaced from each other. Meanwhile, the partitioning unit **38** tapers from the triggering room **312** to the electric discharging room **313**. A control device **4** is connected to the first anode unit **32**, the first cathode unit **35**, the second anode unit **33**, and the second cathode unit **37** respectively. The control device **4** can input positive voltage into the first anode unit **32** and the second anode unit **33** and input negative voltage into the first cathode unit **35** and the second cathode unit **37** to thereby control the first anode unit **32** and the first cathode unit **35** to execute the electric discharge and control the second anode unit **33** and the second cathode unit **37** to execute the electric discharge.

Referring to FIG. **3** and FIG. **4**, during an operation of the vacuum cathode arc-induced pulsed thruster **3**, the control device **4** controls the first anode unit **32** and the first cathode unit **35** to interact and induce the electric discharge to thereby generate an electric arc between the first anode unit **32** and the first cathode unit **35**. The electric arc is concentrated on a surface of the first cathode unit **35** to form a cathode spot. The extremely high temperature of the cathode spot then causes the thermionic emission and generates plasma. The plasma is further discharged to the triggering room **312** to thereby generate thrust initially. Meanwhile, the plasma is generated from the micro-explosion and the evaporation of the first cathode unit **35**, and that will consume carbon formed the surface of the first cathode unit **35** and a surface of the insulating fuel layer **34**.

Referring to FIG. **5** and FIG. **6**, the plasma enters into the electric discharging room **313** from the triggering room **312** to thereby form a channel in the electric discharging room **313**. Simultaneously, the control device **4** actuates the second anode unit **33** and the second cathode unit **37** to interact and induce the electric discharge. The electric discharge then allows the plasma in the electric discharging room **313** to induce an interaction of electric field and magnetic field to further generate Lorentz force and accelerate the thrust. Moreover, because the insulating fuel layer **34** is made of Polytetrafluoroethylene (sold under the trademark TEFLON™), part of carbon will deposit on the surface of the first cathode unit **35** and the surface of the insulating fuel layer **34** when the plasma is generated from the electric arc to thereby resupply the carbon of the first cathode unit **35** and the insulating fuel layer **34**. Thus, the carbon deposition in this invention will not affect the inducing effect and the electric discharge. Further, it can help resupply the carbon of the first cathode unit **35** and the insulating fuel layer **34** to thereby prolong the service life of the first cathode unit **35** and the insulating fuel layer **34**. Hence, this invention is unlike the conventional thruster which needs extremely high voltage to induce the electric discharge by the spark plug. Meanwhile, the vacuum cathode arc-induced pulsed thruster **3** can avoid the deficiency of poor fire-lighting effect caused when the electrodes of the spark plug of the conventional thruster is covered by carbon. Thus, the vacuum cathode arc-induced pulsed thruster **3** can increase the control precision and inducing precision without being affected by the carbon deposition.

To sum up, the vacuum cathode arc-induced pulsed thruster of this invention takes an advantage of the entire structure which has the housing enclosing the electric discharging room and the triggering room and defining the central axis, the first anode unit and the second anode unit respectively disposed in the triggering room and the electric discharging room, the insulating fuel layer enclosed by the first anode unit, the first cathode unit disposed in the triggering room and spaced from the first anode unit to allow the insulating fuel layer located between the first anode unit and the first cathode unit, the main insulating layer enclosed by the first cathode unit, and the second cathode unit penetrating from the triggering room into the electric discharging room along the central axis to thereby be lightweight and have low manufacturing costs, low system complexity, and less energy consumption. Further, carbon deposition caused during an electric discharging process is prevented from affecting an inducing effect to thereby prolong the service life of the thruster and increase the control precision and inducing precision effectively.

While the embodiments of this invention are shown and described, it is understood that further variations and modifications may be made without departing from the scope of this invention.

What is claimed is:

1. A vacuum cathode arc-induced pulsed thruster comprising:

a housing defining a central axis and having an inner peripheral wall, with a triggering room and an electric discharging room respectively enclosed by said inner peripheral wall, said triggering room and said electric discharging room being in communication with each other;

a first anode unit and a second anode unit respectively disposed in said triggering room and said electric discharging room, said first anode unit and said second anode unit fitting said inner peripheral wall of said housing respectively and spaced from each other;

an insulating fuel layer surrounded by said first anode unit;

a first cathode unit disposed in said triggering room and spaced from said first anode unit, with said insulating fuel layer located between said first anode unit and said first cathode unit;

a main insulating layer surrounded by said first cathode unit; and

a second cathode unit disposed in said housing and inserted from said triggering room into said electric discharging room along said central axis;

wherein said first anode unit, said insulating fuel layer, said first cathode unit, and said main insulating layer are in concentric relationship with one another around said central axis of said housing.

2. The vacuum cathode arc-induced pulsed thruster according to claim **1**, further comprising a control device connected to said first anode unit, said first cathode unit, said second anode unit, and said second cathode unit respectively.

3. The vacuum cathode arc-induced pulsed thruster according to claim **1**, wherein said insulating fuel layer is made of Polytetrafluoroethylene (sold under the trademark TEFLON™).

4. The vacuum cathode arc-induced pulsed thruster according to claim **1**, wherein a partitioning unit projects from said inner peripheral wall of said housing so that said first anode unit and said second anode unit are spaced from each other.

5. The vacuum cathode arc-induced pulsed thruster according to claim **4**, wherein said partitioning unit tapers from said triggering room to said electric discharging room.

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