AUSTRALIA

20679/88

Patents Act 1952

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APPLICATION FOR A STANDARD PATENT

LODGED AT SUB-OFFICE
18 JAN 1988
Adelaide

~~I~~/We THE COMMONWEALTH OF AUSTRALIA, Care of the Secretary, Department of Defence, Anzac Park West Building, Constitution Avenue, Canberra Australian Capital Territory, Commonwealth of Australia

~~of~~

hereby apply for the grant of a Standard Patent ~~Patent of Addition~~ for an invention entitled

602109

"IMPROVEMENTS IN PLASMA GENERATORS"

FEE STAMP TO VALUE OF
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which is described in the accompanying provisional ~~complete~~ specification.

For a Convention application — details of basic application(s) —

NUMBER	COUNTRY	DATE OF APPLICATION
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APPLICATION ACCEPTED AND AMENDMENTS
ALLOWED 18-7-90

Our ~~My~~ address for service is COLLISON & CO., Patent Attorneys, 117 King William Street, Adelaide, South Australia, 5000.

Dated this 18th day of January, 19 88

THE COMMONWEALTH OF AUSTRALIA,
By Its Patent Attorneys,
COLLISON & CO.

ALUN THOMAS (Signature)
Attorney for the Applicant

LODGED AT SUB-OFFICE
18 JAN 1988
Adelaide

To:

THE COMMISSIONER OF PATENTS

This form must be accompanied by either a provisional specification (Form 9 and true copy) or by a complete specification (Form 10 and true copy).

‡ 56908

Form 7

COMMONWEALTH OF AUSTRALIA
Patents Act 1952

DECLARATION IN SUPPORT OF AN APPLICATION FOR A PATENT OR PATENT OF ADDITION

INSTRUCTIONS

In support of the Application made by

(a) Insert FULL names of applicant(s)

(a) THE COMMONWEALTH OF AUSTRALIA

(b) Insert "of addition" if applicable

(hereinafter called "applicant(s)" for a patent (b)

for an invention entitled

(c) Insert TITLE of invention

(c) "IMPROVEMENTS IN PLASMA GENERATORS"

(d) Insert FULL name and address(es) of declarant(s) (See Note 1)

I/~~We~~ (d) JEFFREY PATTERSON, Assistant Secretary of Exports and International Programs

Anzac Park West Building, Constitution Avenue, Canberra, Australian Capital Territory, Commonwealth of Australia

do solemnly and sincerely declare as follows:

~~1. I am/We are the applicant(s)~~

(or, in the case of an application by a body corporate)

1. I am/~~We are~~ authorized to make this declaration on behalf of the applicant(~~s~~).

~~2. I am/We are the actual inventor(s) of the invention.~~

(or, where the applicant(s) is/are not the actual inventor(s))

(e) Insert FULL names and addresses of actual inventor(s)

2. (e) ISTVAN KRISTOF VARGA

22 Bradey Road, Windsor Gardens, State of South Australia, Commonwealth of Australia

is/~~are~~ the actual inventor(~~s~~) of the invention and the facts upon which the applicant(~~s~~) is/~~are~~ entitled to make the application are as follows:—

(f) Recite manner in which applicant(s) derive(s) title from actual inventor(s) (See Note 2)

(f) The Applicants are the assignees of the actual Inventor.

(g) Insert PLACE of signing

Declared at (g) Canberra ACT.

(h) Insert DATE of signing

Dated (h) 5th August 1988

(i) Signature(s) of declarant(s)

(i) J. Patterson

JEFFREY PATTERSON, Assistant Secretary of Exports and International Programs

NOTE
No legalization or other witness required

TO: The Commissioner of Patents

(12) PATENT ABRIDGMENT (11) Document No. AU-B-20679/88
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 602109

(54) Title
IMPROVEMENTS IN PLASMA GENERATORS

International Patent Classification(s)
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(60) Related to Provisional(s) : PI3733 PI6336

(71) Applicant(s)
THE COMMONWEALTH OF AUSTRALIA

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(56) Prior Art Documents
US 3655508
WO 86/06922

(57) Claim

1. A plasma generator which allows both electrons and ions to oscillate in an applied field at low frequency excitation with electrons and ions moving in opposite directions, characterised by two sources of ions and electrons at opposite sides of a plasma chamber to provide an increased and more efficient plasma, within the plasma chamber and an electrode in the plasma chamber which is polarised to extract or utilize electrically neutral or positive or negative charged particles generated in the plasma chamber.

3. A plasma generator having a plasma chamber and two sources ions and electrons consisting of two plain cylindrical magnetrons at opposite ends of the plasma chamber, the chamber and the two magnetrons being pumped through by a high vacuum pumping system, the magnetrons each having means to produce electrons and including magnetic means to cause the electrons to rotate and spiral and ionize gas atoms or molecules introduced to the magnetrons to produce a plasma region in the chamber and means to establish an axial oscillation of electrons and ions in opposite directions, the chamber including an electrode adjacent to the plasma region which is polarised to extract or utilize electrically neutral or positive or negative charged particles generated in the plasma chamber.

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COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE:

Class Int. Class

Application Number :
Lodged :

Complete Application No. :
Specification Lodged :
Published :

Priority:

Related art:

This document contains the amendments made under Section 49 and is correct for printing.

TO BE COMPLETED BY APPLICANT

Name of Applicant:
THE COMMONWEALTH OF AUSTRALIA

Address of Applicant: care of The Secretary, Department of Defence, Anzac Park West Building, Constitution Avenue, Canberra, Australian Capital Territory, Commonwealth of Australia.

Actual Inventor:
ISTVAN KRISTOF VARGA

Address for Service: COLLISON & CO., Patent Attorneys, 117 King William Street, Adelaide, South Australia, 5000.

Complete Specification for the invention entitled:

"IMPROVEMENTS IN PLASMA GENERATORS"

The following statement is a full description of this invention, including the best method of performing it known to ~~me:~~ us:

A000345 12/08/88

PATENT, TRADE MARKS & DESIGNS SUB-OFFICE
12 AUG 1988
SOUTH AUSTRALIA

This invention relates to techniques which may be used to expand and intensify plasma formed in a working chamber for deposition of ions and atoms onto substrates and for other purposes.

In the last two decades, but particularly in recent years, significant developments have taken place in the area of plasma generation.

These have been prompted by the usefulness of plasma in all aspects of semi-conductor technology and by an ever increasing number of new applications.

Some of the areas where plasma, or its separated charged particles are used, are as ion sources, in ion rockets, in nuclear physics, in heavy-ion science, in ion plating, in crystal growth also known as ion beam epitaxy, synthesis of compound materials also known as plasma polymerization, in reactive sputtering, in ion sputtered activated reactive evaporation, in surface analysis in medical applications, in surface treatment in ion-assisted thin film deposition and in lasers and in many other applications.

As an example of the art, reference may be had to the proceedings of the International Engineering Congress, ISIAT'83 and IPAT'83 Kyoto (1983) in which a plasma system is described which was used for plasma oxidation of silicon surfaces as used in VLSI production, but the present invention has many applications besides these.

Also reference may be had to the specification of United States Patent No. 3660715 in the name of Richard F. Post assigned to the United States Energy Commission which relates to plasma generator using a stack of pulsed washers to release ionize and heat the gas. This present invention relates to improvements in plasma generators as described in our earlier Patent Application No. PCT/AU86/00128.

The present invention generally consists of a plasma generator which allows both electrons and ions to oscillate in an applied field at low frequency excitation with electrons and ions moving in opposite directions, but with two sources of ions and electrons to provide increased and more efficient deposition rates.

The invention also proposes improvements in plasma generators, particularly in the fragmentation and ionization of gas molecules introduced into such generators for some of the purposes discussed above.

In our earlier Patent Application, we discussed introduction of gases for ionization in the plasma generation region of the plasma generator but this invention also includes the proposal to introduce alternative methods of gas fragmentation to introduce fragmented gas particles into the plasma. In one form, therefore, the invention is said to reside in a plasma generator which allows both electrons and ions to oscillate in an applied field at low frequency excitation with electrons and ions moving in opposite directions, characterised by two sources of ions and electrons at opposite sides of a plasma chamber to provide an increased and more efficient plasma, within the plasma chamber and an electrode in the plasma chamber which is polarised to extract or utilize electrically neutral or positive or negative charged particles generated in the plasma chamber.

Such a plasma generator may include a thermal fragmenter.

Alternatively, the invention may be said to reside in a plasma generator having a plasma chamber and two sources ions and electrons consisting of two plain cylindrical magnetrons at opposite ends of the plasma chamber, the chamber and the two magnetrons being pumped through by a high vacuum pumping system, the magnetrons each having means to produce electrons and including magnetic means to cause the electrons to rotate and spiral and ionize gas atoms or molecules introduced to the magnetrons to produce a plasma region in the chamber and means to establish an axial oscillation of electrons and ions in opposite directions, the chamber including an electrode adjacent to the plasma region which is polarised to extract or utilize electrically neutral or positive or negative charged particles generated in the plasma chamber.

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Preferably, the means to produce oscillation of electrons and ions comprises magnetic mirror means, the outlet of each of the magnetrons adjacent to the chamber whereby to increase significantly ion, electron interaction to facilitate multiple ionization and additionally to enhance neutral particle ionization.

Alternatively, the means to produce oscillation of the ions and electrons in the chamber may include an alternating potential difference between each magnetron and the chamber, the alternating potential difference being out of phase by 180° between the two magnetrons so that the ions from one magnetron and electrons from the other magnetron may be the same volume space within the chamber at the same time and vice versa.

Each of the magnetrons of this invention may have means to cause the electrons to rotate comprising a cylindrical anode and an axial magnet thereby forming a confined plasma.

The plasma generator of this form of the invention may further include a thermal fragmenter to assist in the fragmentation of gas molecules introduced into the chamber.

The thermal fragmenter may be placed into the chamber adjacent to, or extending into the plasma region formed within the chamber and the thermal fragmenter may be floated at the plasma potential.

In one preferred form, the thermal fragmenter may comprise a hollow heated filament of refractory material through which the gas to be ionized is passed with a vent hole in the filament in the region of the plasma region to allow the escape of fragmented molecules of the gas.

Such a filament may be made from a metal selected from tantalum, platinum, or other suitable material depending upon the type of gas which is to be fragmented and the proposed conditions in the chamber.

Alternatively, the thermal fragmenter may comprise an oven which includes a high surface area packing over which the gases to be fragmented, are passed.

Such an oven may have electrical heating by means of an electrical filament around the oven.

The packing may be a fibre mesh of a metal selected from tantalum or platinum or may be a carbon fibre packing whereby the nature of the packing is selected for the type of gas to be fragmented.

Such a thermal fragmenter may be inserted into the plasma chamber in one wall of the plasma chamber and its junction with the wall of the chamber may be cooled and also the electrical elements extending into the thermal fragmenter may also be cooled.

By means of this present invention, considerable benefits can be obtained. The second magnetron can be identical in all respects to the first magnetron and they may each use the main magnet of the other as an opposite end of a magnetic mirror system which enables confinement of the plasma within the plasma chamber.

The temperature to which the thermal fragmenter may be raised will depend upon the type of gas to be fragmented and the materials of the fragmenter which may act as a catalyst for the fragmentation. For instance, in the coating of silicon onto a substrate, a gas which may be used is silane (SiH_4) which requires a temperature of about 300°C or greater. Alternatively, if the gas to be fragmented is methane, so as to give a carbon deposition, a temperature of between 850°C or greater is required.

For the process of the present invention, carrier gas is introduced into the magnation chamber to pass over the magnetron filament in the normal manner. For instance, a carrier gas such as argon, neon, nitrogen or other noble gas may be used. Once the carrier gas has ionized it will ion irradiate the substrate in the plasma chamber to assist in keeping the surface of the substrate clean and assist in film formation by neutral or ionized molecules or atoms.

The plasma chamber of the present invention including a thermal fragmenter may be used for any particular purpose for which ionized energetic atoms or gas molecules are required to be deposited onto a substrate to form films of desired characteristics. An electric field between the thermal fragmenter and the substrate may be used to draw the ions onto the substrate.

One example of this is in the application of a hard durable diamond like carbon coating to a semi-conducting substrate. For this, the temperature of the thermal fragmenter is raised to about 850°C and methane gas is passed into the thermal fragmenter to project atoms of carbon and hydrogen into the plasma which are then ionized mainly by collisions with electrons in the plasma and then by suitable charging of the substrate the required carbon ions may be drawn onto the substrate surface to form the hard durable diamond like coating.

The thermal fragmenter of the various embodiments of the present invention, may be designed such that in affect, a jet of atoms of the fragmented gas is projected from it into the plasma where they are ionized before being drawn onto the substrate and, if necessary, by suitable movement of the thermal fragmenter or the substrate, various type and layers of coatings may be provided onto the substrate. There may, for instance, be several thermal fragmenters in a plasma chamber each adapted in turn to provide a particular coating onto the substrate with each fragmenter being moved into the required position as desired or the substrate being moved to be positioned adjacent to each fragmenter as desired.

Benefit may be obtained from the thermal fragmenter incorporated in the present invention if the atoms of the thermally fragmented gas molecules are ionized as they leave the fragmenter. This can be achieved if instead of a D.C. electrical power, an R.F. or combination of D.C. and R.F. power is used to heat a suitably structured fragmenter. The frequency and power input of the R.F. component is adjusted to give optimum ionization of atoms as the atoms are emerging through the aperture or apertures from the hollowed filament of the fragmenter.

This then generally describes the present invention, but to assist with understanding of the invention, reference will now be made to the accompanying drawings which show preferred embodiments of the invention and in which the drawings are schematic diagrammatic views of plasma generators.

In the drawings:-

FIG. 1 is a plasma generator incorporating two magnetrons,

FIG. 2 is one form of thermal fragmenter suitable for the present invention,

FIG. 3 shows a second form of thermal fragmenter suitable for the present invention, and

FIG. 4 shows a plasma chamber including a thermal fragmenter.

Now looking closely at the drawings and in particular FIG. 1, it will be seen that the main components of the plasma generator are a first magnetron 1, a second magnetron 2 and an evacuated plasma chamber 3. The magnetrons 1 and 2 are arranged on either side of the plasma chamber 3 and diametrically opposed to each other on a line which may be referred to as a magnetron axis.

Now looking particularly at the magnetron 1, the initial ionization takes place in the magnetron 1 which has an electron source 7 provided by a heated tungsten or tantalum or other filament placed at or near the magnetron axis. A cylindrical anode 8 and an axial magnet 11 form a magnetic field such that electrons emitted from the filament 7 are confined radially and prevented by the magnetic field from reaching the anode 8. The presence of the electric field and magnetic field causes the electrons emitted to rotate and spiral and as these become more energetic they ionise gas atoms of molecules introduced to the inlet 5 to form a confined plasma which may persist as long as suitable conditions are maintained. An opening 4 to the plasma chamber 3 extends to an evacuation apparatus (not shown).

According to this invention, the intensity of the plasma is increased by establishing an axial oscillation of electrons and ions. This may be achieved if consideration is given to the rate at which ions may respond to axial forces. Generally with respect to electrons in a plasma, ions are considered stationary or of low mobility due to the very much larger mass compared to electrons. However, it has been found that if a suitable low frequency potential is applied along the magnetron axis, both electrons and positive ions may be made to oscillate axially. Negative ions, which are the result of electron attachment, may also move in opposite directions to the movement of the positive ions so that

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these are also subjected to collision with other particles. Ions achieve no nett movement if a high frequency potential is applied.

The nature of this mass transport is such that the particles with opposite charge polarity will move in opposite directions under the influence of the applied potential and this transportation mode will increase significantly the probability of ion-electron and ion-ion interaction, facilitating ionized molecule fracture and multiple ionization in addition to the enhancement of the neutral particle ionization.

The frequency used may depend on the nature of the ions but with gas ions produced by admitting Hydrogen, Argon, Nitrogen, Methane or other similar gases or vapours to the magnetron, it has been found that a frequency of oscillation of 50 Hz is effective, but that frequency can be selected over a wide range. Beyond 1MHz, however, ions can be considered to be unaffected by the applied field.

Now still looking only at one magnetron to facilitate the energy transfer described above, the magnetron chamber 1 and vacuum 3 combination is used such that at a low frequency alternating voltage is applied between the magnetron 1 and the vacuum 3 as indicated by symbol 9. To contain the plasma and to enhance further process of ionization, a magnetic field in the form of a magnetic mirror is formed by the field of electromagnet 11 and electromagnet 12. The electromagnet 12 is, however, the electromagnet of a second magnetron 2 which in a similar manner to magnetron 1 has a filament 13 producing electrons which are confined by means of cylindrical anode 14 and electromagnet 12 and by which electrons are caused to spin and to ionize molecules of gas to produce a further plasma which may then, in a similar manner to the first magnetron, enter the main plasma chamber 3.

Once the plasma is formed, the electromagnets 11 and 12, as discussed above, act as a magnetic mirror and maintain the plasma within the chamber 3.

While the magnetic mirror has little or no effect on the ions, it strongly influences electrons under static conditions. However, when the axial potential variation is applied above a certain voltage value, electrons are removed in an axial direction with sufficient energy to ionize additional gas particles. They will move alternatively between the magnetron 1 and the vacuum chamber 3 and the magnetron 2, as driven by the low frequency voltage gradient 9 and the corresponding voltage gradient on the other magnetron 2, shown by 16. Similarly, the positive ions are made to move by the same potential variation in the opposite direction to that of the electrons or negative ions.

As was mentioned earlier, the result of interaction with the charged particles with each other or with neutral atom or molecules generates more ionized particles which will also be influenced by the low frequency axial potential.

The low frequency potentials 9 and 16 may be utilized 180° out of phase so that electrons are available at all times and surface charging of a substrate 18 on an electrode 17 within the plasma chamber can be reduced or eliminated with an appropriate biased potential.

The electrode 17 supporting the substrate 18 may be positioned so that ion deposition from the plasma may occur, provided a suitable biased potential is provided to electrode 17 under suitable conditions. The bias of the off-axis substrate 18 may also be amended or include the possibility of using pulsed voltage 20 of square or sinusoidal wave form or other form of suitable period and mark to space ratio to optimise the control over the surface charging affects.

As we have discussed earlier, the production of a plasma within the plasma chamber may be enhanced by introducing of the gas to be ionized directly into the plasma chamber 3 rather than into the ionizing gas inlets 5 and 6. If the gas to be ionized such as methane is not allowed to enter through the gas inlets 5 and 6, then poisoning of the electrodes 7 and 13 will be reduced or not occur. Hence, it is necessary to provide some form of device to introduce gas molecules or fragmented gas molecules into the for instance, argon, plasma. This may be done by use of the thermal fragment as shown in FIGS. 2 and 3.

In the thermal fragmenter shown in FIG. 2, a flange 20 fitted into the wall 21 of the plasma chamber may support an oven 22. Inside the oven 22 is a fine tantalum wire wool or other suitable high surface area material 23 which is heated by means of electrical wires 24 which extend through the flange 20. The electrical wire 24 extend into a heating element 25 and the walls of the oven 22.

It will be realised, however, that other forms of heating for the oven may also be used.

A gas inlet 26 is provided into the oven so that gas to be fragmented may be introduced into the oven before being ejected out of the relatively narrow opening 28 into the plasma region shown by 29. The shape and positioning of the relatively narrow opening 28, opening into the plasma from the oven may be used to direct gas atoms into the plasma in such a way that they can be directed into the required patterns or arrangements onto the substrate 32. The flange 20 may include cooling coils 30 to cool the flange and a cooling jacket 31 to cool the gas inlet.

FIG. 3 shows an alternative form of thermal fragmenter in which gas is allowed into an inlet 40 to pass into arms 41 and 42, which extend through a flange 43 in the wall 44 of a plasma chamber to direct gas into a heating filament generally shown by 46. The arms 41 and 42 are cooled by means of cooling jackets 47 and are insulated from each other so that an electrical current may be passed in through the electrodes 48 and 49 so that the filament 46 acts as a heated filament. Hence, gas which is passed in through the opening 14, is heated as it passes into the filament and is thermally cracked before exiting through aperture 50 in the plasma region 51.

In this particular embodiment, the gas entering is methane and hence, disassociated atoms of carbon and hydrogen are ejected through the aperture 50 and, by use of suitable potentials, may be deposited onto the substrate 52.

Once again, cooling coils 53 may be provided in the flange 43.

FIG. 4 shows an arrangement of plasma generator which has a first magnetron 60 and a second magnetron 61 with a plasma chamber 62 between the two magnetrons and with a thermal fragmenter generally shown as 63 extending into the plasma chamber and also a substrate holding electrode 64 extending into the plasma chamber.

In this embodiment, the magnetrons 60 and 61 act in exactly the same manner as the magnetrons 1 and 2 as shown in FIG. 1, but the gas which enters through the inlet 65 for magnetron 60 and 66 for magnetron 61 is only the carrier gas such as argon and not the gas to be ionized such as methane or silane. The methane or silane is introduced through gas aperture 67 into thermal fragmenter 63 which is of the type as discussed in FIG. 2.

By this means, the filaments 68 and 69 of the magnetron 60 and 61 respectively have less tendency to become poisoned by the introduction of the gas to be ionized adjacent them and hence, more efficient plasma generation occurs.

As discussed earlier, there may be a number of thermal fragmenters 63 mounted, for instance, on a turntable within the plasma generator so that any one of the thermal fragmenters may be selected so that at various times during the deposition process, for instance, onto a substrate 70 on the electrode 64 different atoms of gas molecules may be deposited onto the substrate 70 by means of selection of different thermal fragmenters.

It will be seen that by this invention, there is provided an arrangement where, owing to the fact that two magnetrons are each producing plasmas of ions and electrons and, preferably, when operated 180^{o} out of phase, there will be ions and electrons available at the substrate surface if ion deposition is being carried out or on any other form of target or application which the plasma generator, of the present invention, may be applied and, as such, much more efficient use of the plasma is obtained.

In particular, with use of a substrate as discussed above, the present invention may increase deposition rates while maintaining quality of adhesion, hardness and thickness consistency on diamond like carbon films and, further, it can reduce the time taken to process a hard carbon coating by 50% or more.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A plasma generator which allows both electrons and ions to oscillate in an applied field at low frequency excitation with electrons and ions moving in opposite directions, characterised by two sources of ions and electrons at opposite sides of a plasma chamber to provide an increased and more efficient plasma, within the plasma chamber and an electrode in the plasma chamber which is polarised to extract or utilize electrically neutral or positive or negative charged particles generated in the plasma chamber.

2. A plasma generator as in claim 1 further including at least one thermal fragmenter.

3. A plasma generator having a plasma chamber and two sources ions and electrons consisting of two plain cylindrical magnetrons at opposite ends of the plasma chamber, the chamber and the two magnetrons being pumped through by a high vacuum pumping system, the magnetrons each having means to produce electrons and including magnetic means to cause the electrons to rotate and spiral and ionize gas atoms or molecules introduced to the magnetrons to produce a plasma region in the chamber and means to establish an axial oscillation of electrons and ions in opposite directions, the chamber including an electrode adjacent to the plasma region which is polarised to extract or utilize electrically neutral or positive or negative charged particles generated in the plasma chamber.

4. A plasma generator as in claim 3 wherein the means to produce oscillation of electrons and ions comprises magnetic mirror means at the outlet of each of the magnetrons adjacent to the chamber whereby to increase significantly ion electron interaction to facilitate multiple ionization and additionally to enhance neutral particle ionization.

5. A plasma generator as in claim 3, wherein the means to produce oscillation of the ions and electrons in the chamber includes an alternating potential difference between each magnetron and the chamber, the alternating potential difference being out of phase by 180° between the two magnetrons so that ions from one magnetron and electrons from the other magnetron may be in the same volume space within the chamber at the same time and vice versa.

6. A plasma generator as in any one of claims 3 to 5 wherein the means to cause the electrons to rotate in each of the magnetrons is a cylindrical anode and an axial magnet thereby forming a confined plasma.

7. A plasma generator as in any one of claims 3 to 6 further including a thermal fragmenter to assist in the fragmentation of gas molecules introduced into the chamber.

8. A plasma generator as in claim 7 wherein the thermal fragmenter is placed in the chamber adjacent or extending into the plasma region.

9. A plasma generator as in claim 8 wherein the thermal fragmenter extends into the plasma region and is floated at the plasma potential.

10. A plasma generator as in any one of claims 7 to 9 wherein the thermal fragmenter is a hollow heated filament of refractory metal through which the gas to be ionized is passed with a vent hole in the filament in the region of the plasma region to allow the escape of the fragmented molecules of the gas.

11. A plasma generator as in claim 10 wherein the filament is made from a metal selected from tantalum, platinum or other suitable material depending upon the type of gas which is to be fragmented and the proposed conditions in the chamber.

12. A plasma generator as in any one of claims 7 to 9 wherein the thermal fragmenter comprises an oven, which includes a high surface area packing over which the gas to be fragmented is passed.

13. A plasma generator as in claim 12, wherein the oven has electrical heating by means of an electrical filament around the oven.

14. A plasma generator as in claim 11 or claim 12 wherein the packing is a fibre mesh of a metal selected from tantalum or platinum or is a carbon fibre packing whereby the nature of the packing is selected for the type of gas to be fragmented.

15. A plasma generator as in any one of claims 7 to 14 wherein the thermal fragmenter is inserted into the plasma chamber through one wall of the plasma chamber and its junction with the wall of the chamber is cooled and electrical elements extending into thermal fragmenter are also cooled.

16. A plasma generator substantially as hereinbefore described with reference to and as illustrated by FIG. 1.

17. A plasma generator including a thermal fragmenter substantially as hereinbefore described with reference to and as illustrated by FIG. 2 to 4.

Dated this 26th day of February 1990.

THE COMMONWEALTH OF AUSTRALIA
By its Patent Attorneys
COLLISON & CO

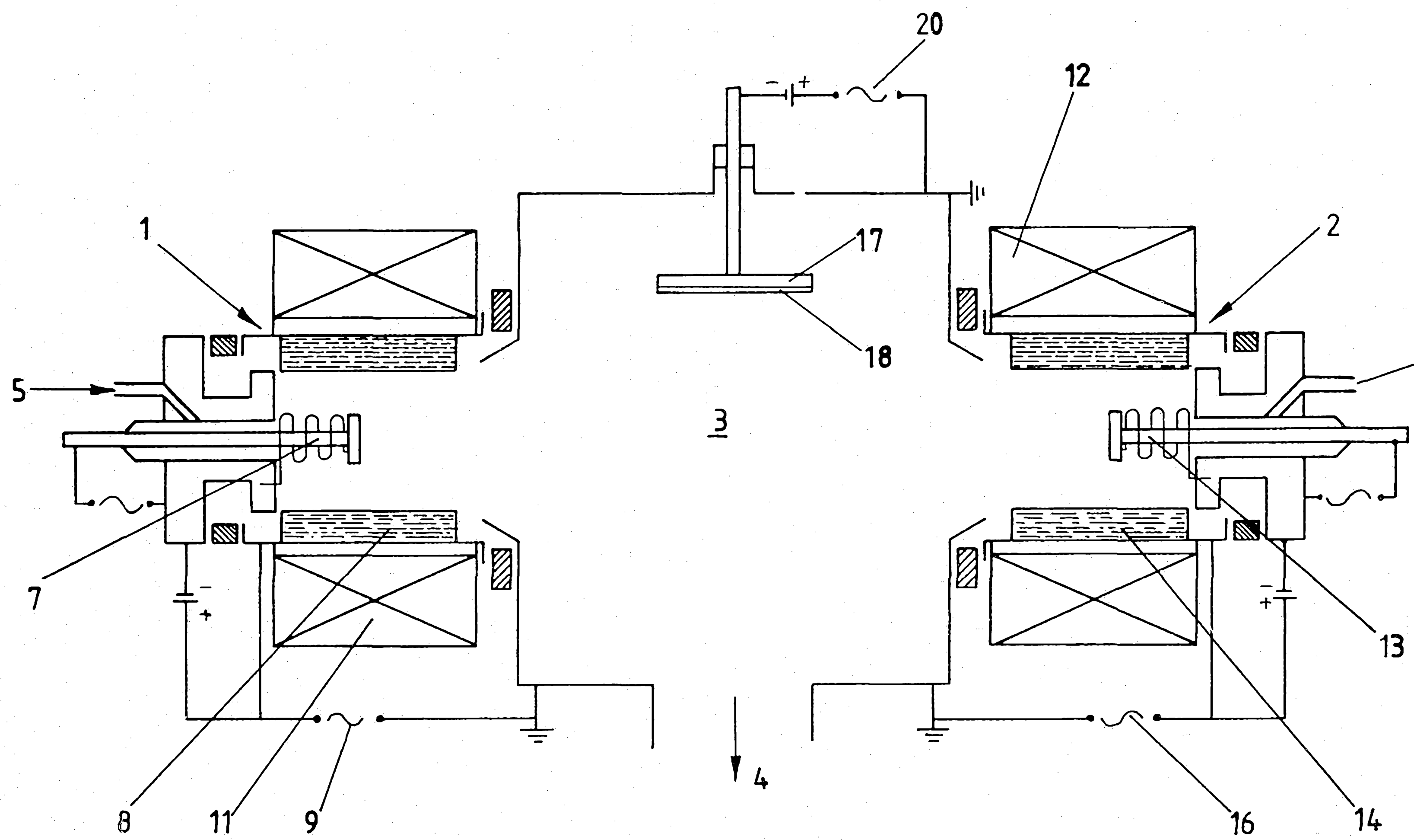

FIG 1

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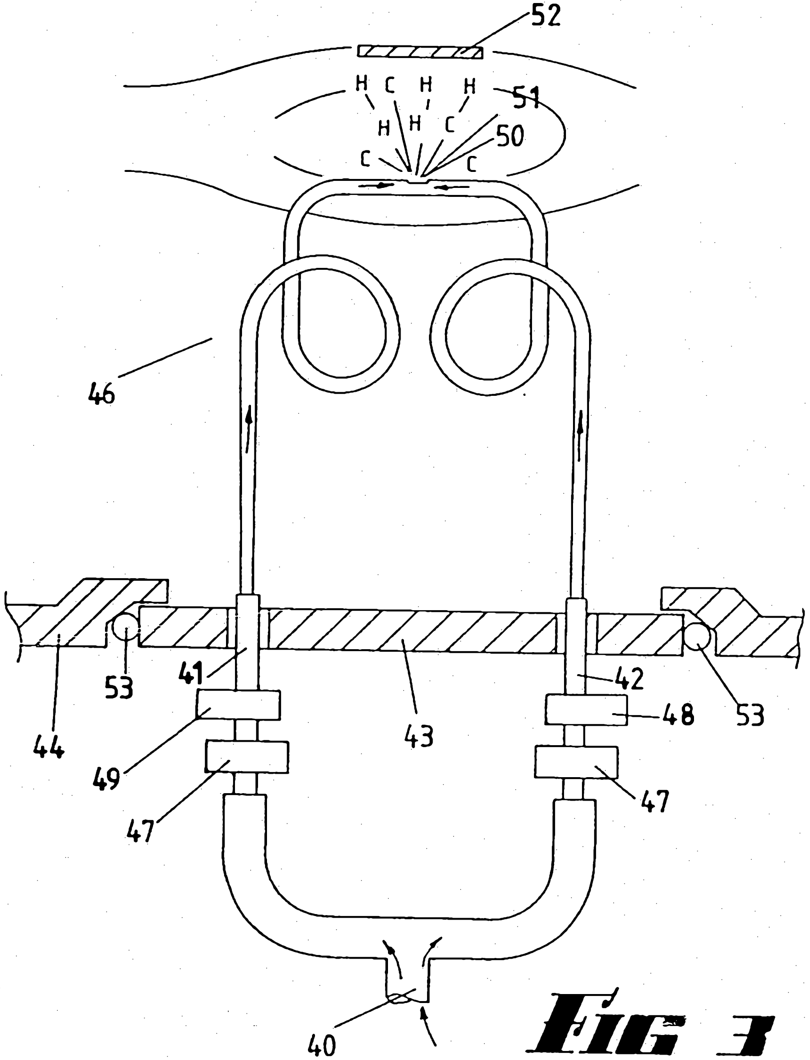
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FIG 3

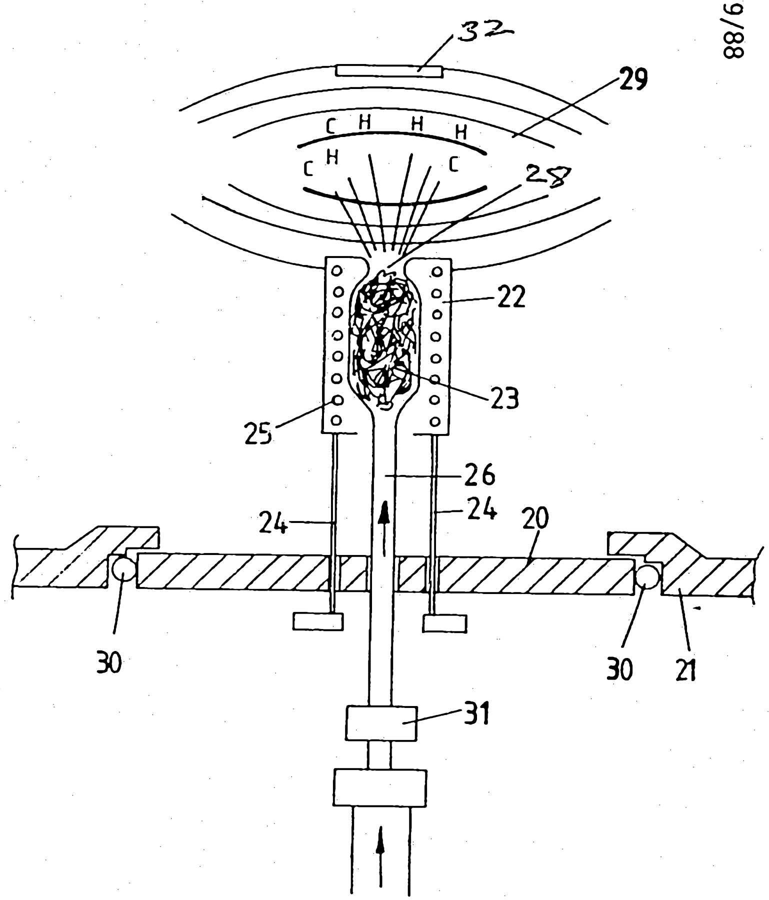
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FIG 2

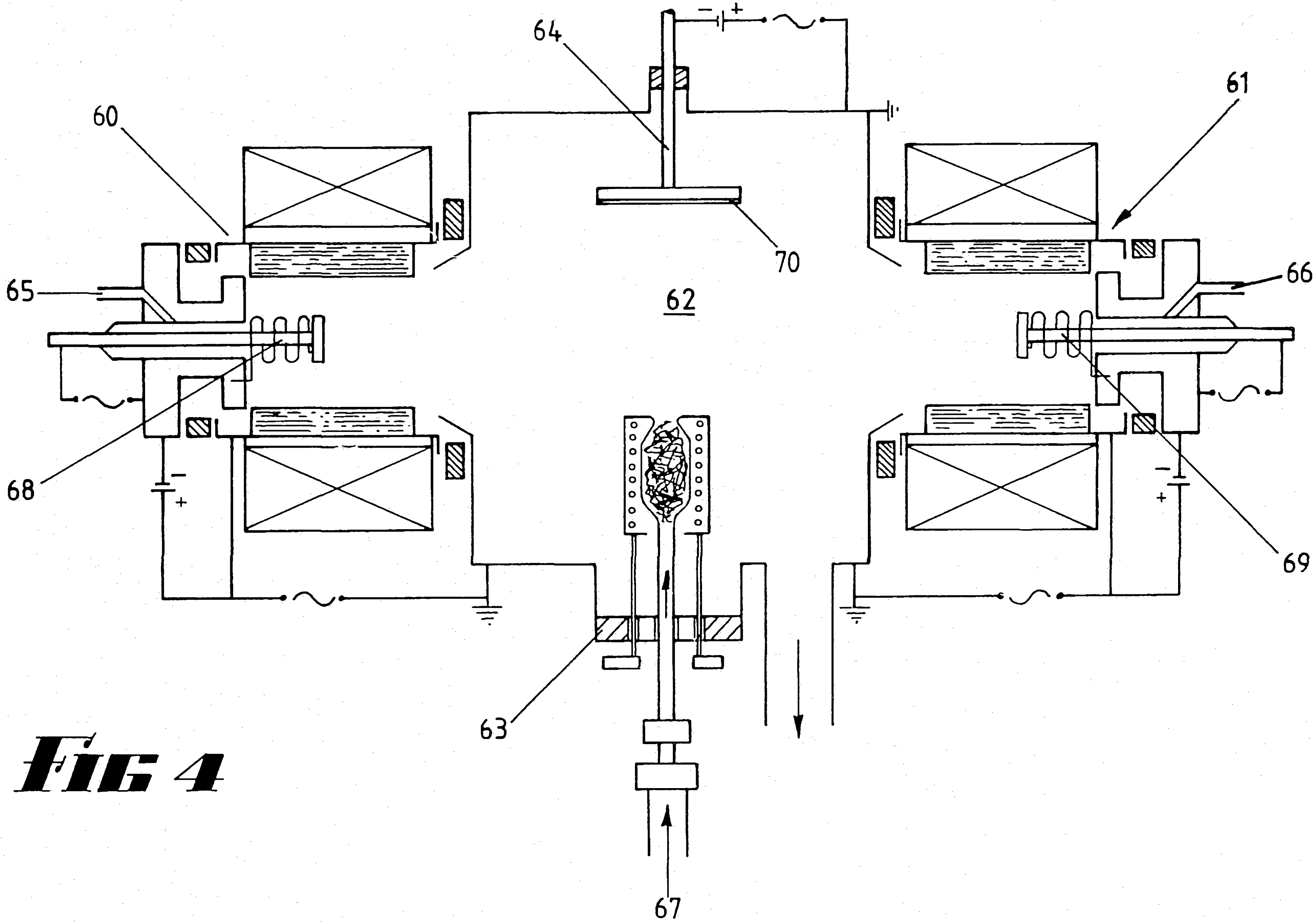

FIG 4

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