

Dugdale et al.

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[54] **NON-THERMIONIC GLOW DISCHARGE DEVICES**

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[58] Field of Search.....313/231, 210, 63; 219/121 EB; 315/111

[56] **References Cited**

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[57] **ABSTRACT**

A glow discharge device comprising an enclosure and means to maintain a suitable gas in the enclosure at a predetermined pressure. An electrode arrangement is either at least partly disposed within the enclosure or forms part of a wall of the enclosure. The electrode arrangement includes one or more anodes, a cathode, and a control electrode. Power supply means are provided to apply a electrical potentials to the anode or anodes said cathode and said control electrode to maintain a first potential difference between an anode and said cathode to generate a first glow discharge, and to maintain a second potential difference between an anode and said control electrode to generate a second glow discharge. The combined first and second glow discharges produces a beam of charged particles, the power intensity of which is controlled by varying the potential applied to the control electrode to vary the glow discharge independently of the potential applied to the cathode.

2 Claims, 3 Drawing Figures

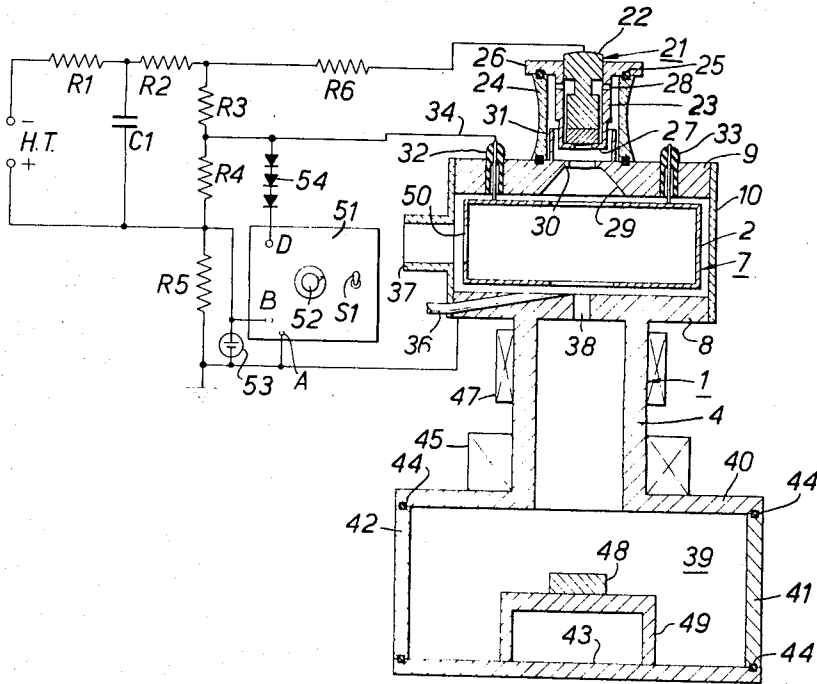
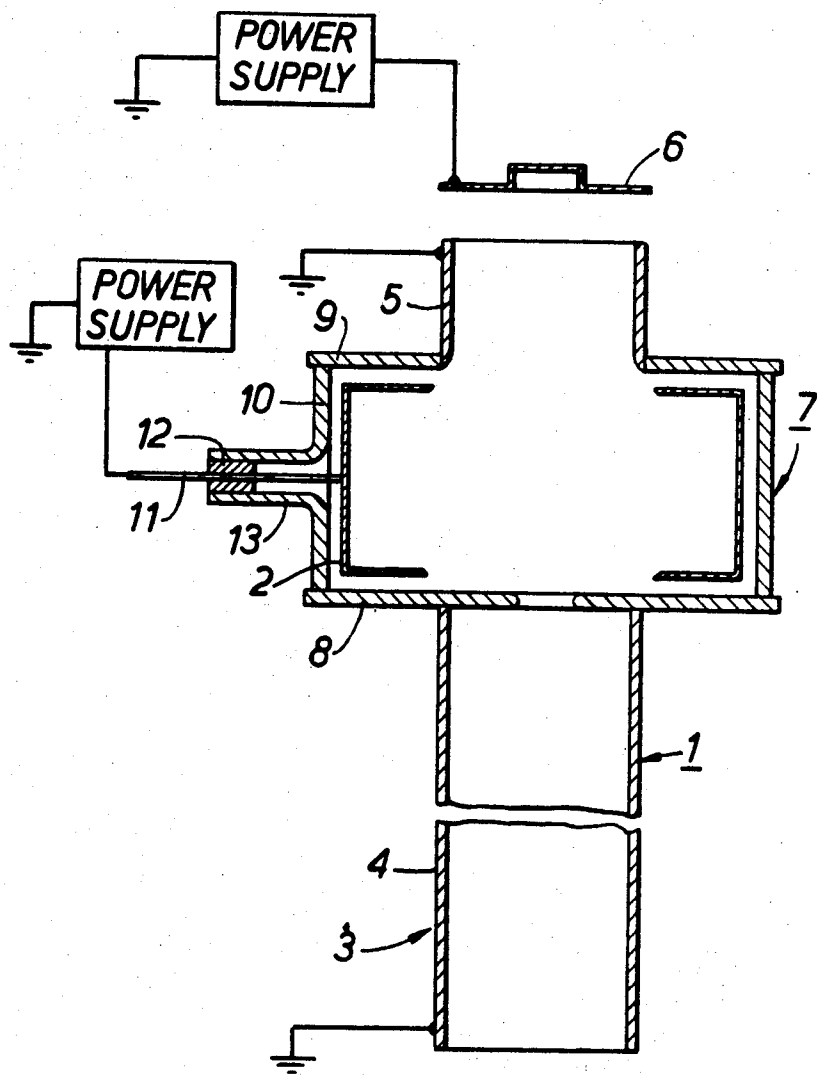


FIG. 1.



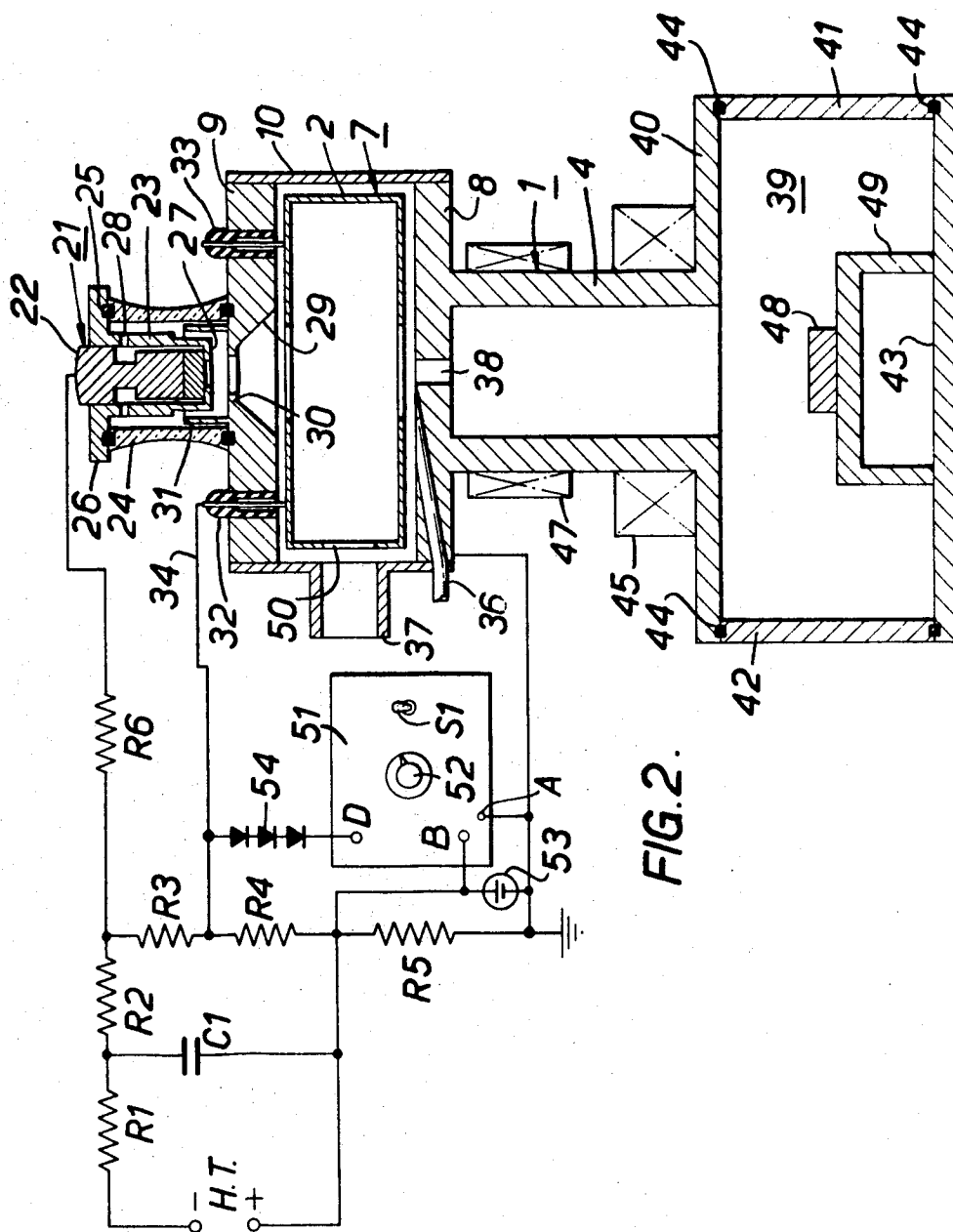
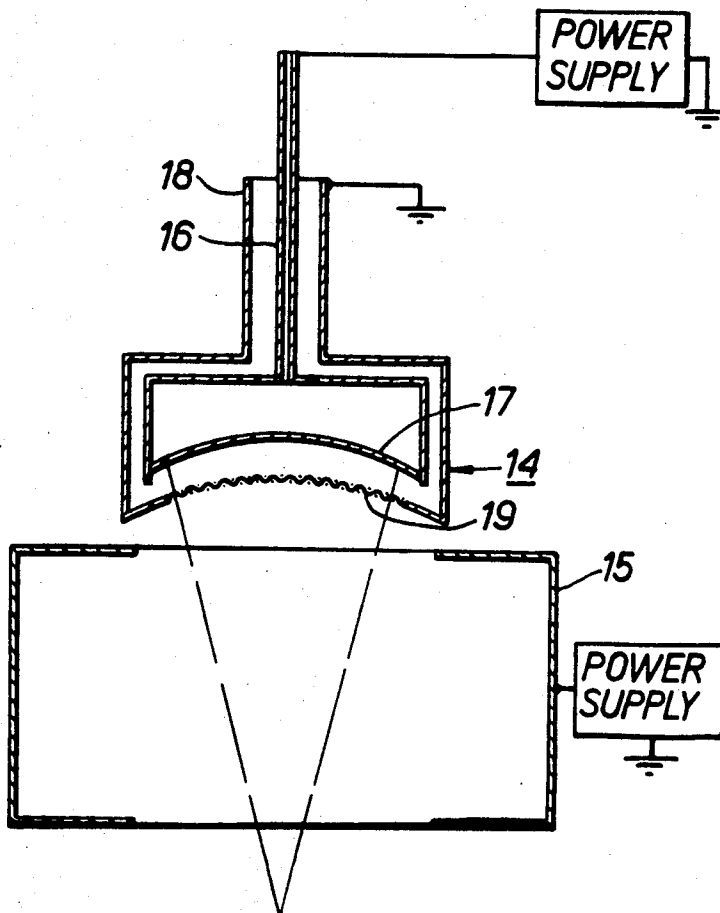


FIG.3.



NON-THERMIONIC GLOW DISCHARGE DEVICES

This invention relates to non-thermionic cathode glow discharge devices, and in particular although not exclusively to glow discharge devices of the type generally disclosed in British Pat. No. 1,145,013 and British Pat. application Ser. No. 48,144/66.

According to the invention there is provided a glow discharge device comprising an enclosure, means to maintain a suitable gas in the enclosure at a predetermined pressure, an electrode arrangement at least partly disposed within or forming part of the enclosure, the electrode arrangement including one or more anodes, a cathode, and a control electrode, a power supply means to apply an electrical potential to said anode or anodes said cathode and said control electrode to maintain a first potential difference between an anode and said cathode to generate a first glow discharge, and to maintain a second potential difference between an anode and said control electrode to generate a second glow discharge, the combined first and second glow discharges producing a beam of charged particles the power intensity of which is controlled by varying the potential applied to the control electrode to vary the glow discharge independently of the potential applied to the cathode.

A sensing means may be provided to obtain a signal indicative of the current flowing in the said beam of charged particles, and means may be provided to use the signal to vary the potential applied to the control electrode in response to the signal to modulate the power intensity of the beam.

The potential difference between an anode and said control electrode is preferably less than a value at which a self sustaining glow discharge accompanied by the emission of a beam of charged particles is produced. Also the potential difference between an anode and said control electrode may be less than a value at which a self sustaining glow discharge accompanied by the emission of a beam of charged particles is produced. In the latter instance the combined effect of the potential difference between an anode and said cathode together with the potential difference between an anode and said control electrode is arranged to generate and maintain a self sustaining glow discharge accompanied by the emission of a beam of charged particles.

According to a feature of the present invention a non-thermionic cathode glow discharge device comprises an enclosure having gas inlet and outlet openings, means to maintain a suitable gas at a predetermined pressure within said enclosure, at least one electrode means at least partly disposed within said enclosure and including an anode, a cathode and a control electrode, means to apply a suitable potential to said anode and said cathode prior to the application of a suitable potential to said control electrode such that when suitable operating potentials are applied to said anode and control electrode a glow discharge is generated and controlled, and a beam of charged particles is produced, the beam being directed towards a treatment zone by the electric fields associated with said anode, cathode, and control electrode.

According to a further feature of the present invention there is provided a non-thermionic cathode glow discharge device comprising an enclosure having gas inlet and outlet openings, means to maintain a suitable gas at a predetermined pressure within said enclosure, at least one electrode assembly at least partly disposed within said enclosure said electrode assembly including an anode, a cathode and a control electrode, means to apply suitable operating potentials to said anode and control electrode to generate a glow discharge prior to the application of a suitable operating potential to said cathode means to apply a suitable operating potential to said cathode such that the said glow discharge is augmented and a beam of charged particles is produced, said beam being directed by the electric fields associated with said anode, and cathode.

The present invention will now be described with reference to the accompanying drawings, which are by way of an example only, and in which:

FIG. 1 shows schematically one form of an electrode assembly of a device according to the invention, and

FIG. 2 shows a device according to the invention employing a modified form of the electrode assembly of FIG. 1;

FIG. 3 shows a further form of an electrode assembly according to the invention.

Referring to FIG. 1 of the drawings there is shown an electrode assembly 1 which is similar to one of the electrode assemblies generally disclosed in British Pat. No. 1,145,013 but modified by the provision of a control electrode 2. The electrode assembly 1 includes a hollow tubular anode 3 formed by two open ended tubes 4 and 5 and a cathode 6 connected to a suitable power supply is positioned adjacent one open end of the anode 3. A substantially right circular cylindrical chamber 7 formed by metallic end walls 8, 9 and 10 is arranged co-axially with respect to the anode 3. Alternatively the wall 10 may be made from an insulating material such as for example glass, in which case the end walls 8 and 9 are electrically interconnected to form anodes.

The electrode 2 is of a substantially annular shape having an open channel shaped cross-section facing inwards. The electrode 2 is connected to a power supply by way of connector 11 and is supported in the chamber 7 by the connector 11 which is located in an insulating bush 12 positioned in a neck portion 13 of the chamber 7.

The cathode 6 is a generally planar disc with a recess formed therein. The recess shapes the equipotential and electric fields lines and assists in focusing the electron beam.

The electrode assembly 1 of FIG. 1 is positioned within a chamber (not shown) which is provided with an inlet opening through which gas is admitted to the interior of the chamber from a source of supply via a suitable valve, and an outlet opening through which the gas within the chamber may be pumped away by a pump to maintain the gas at a predetermined pressure of a few microns of mercury within the chamber. Alternatively the electrode assembly may be constructed such that the cathode chamber 7 and tubes 4 and 5 form a gas tight enclosure similar to the device of FIG. 2.

In one mode of operation of the device the enclosure is evacuated to a gas pressure of a few microns of mercury, the tubes 4 and 5 are earthed and form anodes and a negative potential of up to 10 KV is applied to the control electrode 2 to initiate a glow discharge. A negative potential, of for example, 5 KV to 100 KV is then applied to the cathode 6 with the result that the glow discharge initiated by the potentials applied to the anode and further electrode is augmented, and the gas becomes more ionized. Positive ions so created in the gas within the anode 3 bombard the cathode 6 and cause the cathode to emit electrons which are focussed by the electric fields associated with said anode 3, and cathode 6. By varying the potential applied to the control electrode 2 from a few volts up to 10 KV negative, the intensity of the glow discharge and hence the intensity of the resulting electron beam can be varied.

In a second mode of operation of the device, the gas pressure within the enclosure is maintained at a level at which no glow discharge and no electron beam would be formed when the voltage is only applied to the cathode 6, but which causes a glow discharge to occur and an electron beam to be produced where a negative voltage is applied to the control electrode 2 as well as the cathode. The pressure level is not critical provided that it is less than a value which would permit a self-sustaining glow discharge to occur when a voltage is applied to the cathode 6. A negative potential of 5 KV to 100 KV is then applied to the cathode and the pressure is maintained substantially the same. A negative potential of, for example, 10 KV is then applied to the electrode 2, a glow discharge is thus initiated and the gas in the anode 3 becomes ionized. Positive ions so created in the gas in the anode 3 bombard the cathode 6 with the result that electrons are emitted by the cathode. The electrons are directed and focused into a stream by the electric fields associated with the anode, and cathode.

It will be seen from the above description that the low voltage (relative to that supplied to the cathode) supplied to the control electrode can be varied to control the intensity of the resulting electron beam or to effectively switch on or off the electron beam.

Similarly as the intensity of the beam is also dependent upon the effects of gas pressure, variations of gas pressure in the enclosure may have undesirable effects on the intensity of the electron beam. Variations in the gas pressure affects the ionization of the gas by altering the mean free path between the molecules of the gas and hence the glow discharge will be affected by pressure changes. Changes in pressure will result in changes of the electrical current flowing through the beam. The variations in the current flowing through the beam may be fed back through a suitable electrical circuit to adjust the current supplied to the control electrode 2 to automatically control the glow discharge to compensate for gas pressure changes within the enclosure.

It is to be understood that further electrodes may be provided between the cathode 6 and anode 3 if desired. These further electrodes may be used to focus or deflect the resulting beam of electrons. The cathode need not be provided with a recess portion, and if desired the cathode may be apertured, in which case some of the ions created in the gas within the anode 3 will pass through the aperture, or apertures, in the cathode to produce a stream of ions which are focused and directed by the electric fields associated with the anode 3, cathode 6 and control electrode 2 and any further electrode provided between the anode 3 and cathode 6.

Furthermore the anode 3 may consist of a single tube having the electrode 2 positioned coaxially therein. Alternatively the control electrode 2 may be in the form of an apertured plate positioned adjacent the end of the anode 3 which is opposite to the end at which the cathode 6 is located.

Referring to FIG. 2, the cathode 21 comprises an inner core 22 and an outer flanged sleeve 23, and the cathode 21 is supported and spaced from the end plate 9 of the chamber 7 by an insulator 24 for example, a glass sleeve. O ring seals 25 are provided between the end face of the insulator 24 and the flange 26 of the sleeve 23 and between the end face of insulator 24 and the end plate 9. The sleeve 23 has an interned flange 27 which with the core 22 forms a well similar to that of the cathode 6 of FIG. 1. The core 22 may rest on the interned flange 27 as shown or may be spaced from it, and is supported in the bore of the sleeve 23 at its end remote from the chamber 7. The remainder of the core is of a reduced diameter to provide clearance between the sleeve 23 and the core 22. Holes 28 are provided in the sleeve 23. Internal coolant ducts (not shown) may be provided in the core to enable the core to be cooled by a flow of coolant. A cathode having internal cooling and suitable for use in the apparatus of the present invention is described in our co-pending U.S. application Ser. No. 824,883, commonly assigned now abandoned. If desired at least a part of the cathode may be movable to present a fresh part of the cathode to ion bombardment.

The top plate 9 of the chamber 7 is provided with a truncated conical aperture 29 which corresponds to the tube 5 of FIG. 1. An interned lip 30 is provided at the end of the aperture 29 so that in operation of the apparatus positive ions bombard the cathode over a small area. The plate 9 carries a cylindrical projecting wall 31 which encircles and is spaced from, the lower end of the cathode 21. The wall 31 forms a heat shield and prevents spurious discharges in the space between the cathode and the insulator 24. Two insulator bushings 32 and 33 are provided in the plate 9 to enable electrical connections 34 to be made to the control electrode 2 and to enable the control electrode 2 to be suspended by supports 35 from plate 9.

The chamber 7 is provided with a gas inlet duct 36 and a gas outlet duct 37 which is connected to a pump. The control electrode 2 is provided with a mesh portion 50 in line with the outlet duct 37 to assist the pumping of gas from the interior of chamber 7. The wall 8 is provided with a small diameter hole 38 which interconnects the interior of chamber 7 with the interior of the cylindrical flanged tube 4, to enable the electron beam produced in operation of the apparatus to emerge and pass axially along the tube 4 into the work chamber 39. The work chamber 39 is cubical and is formed by the flange 40 of tube 4 and side walls 41 and 42 and base plate 43. Located in

the work chamber 39 is a work holder 49 which supports the work 48 to be machined by the resulting electron beam. O ring seals 44 are provided between the mating faces of walls 41, 42 and the flange 40 and base plate 43. Access openings (not shown) and windows (not shown) may be provided in one or more of the walls defining the work chamber 39.

An electromagnetic lens 45 and two pairs of electromagnetic deflection coils 47, only one pair of which is shown, are provided externally of the tube 4 to enable the resulting electron beam to be focussed and deflected.

The plates 8 and 9, wall 10, tube 4 and the walls defining the work chamber 39 are metallic and electrically interconnected, and form an anode in operation of the apparatus.

The chamber 7 together with the work chamber 39, the space defined by the cathode 21 and insulator 24, and the space defined by the tube 4, form a substantially gas tight enclosure. If desired the work chamber 39 may be pumped separately to enable different pressures to be maintained in the chamber 7 and work chamber 39, in which case gas inlet and outlet ducts are provided in chamber 39 as well as in chamber 7.

Referring now to the electrical circuit shown in FIG. 2 the cathode 21 is connected via resistors R1, R2, and R6, to the negative H.T. terminal of a high voltage power supply, for example a 30 KV 20 ma power supply. A capacitor C1 is connected between the junction of resistors R1 and R2 and the positive H.T. terminal. Resistors R1 and R2 together with capacitor C1 form a simple smoothing circuit. Two resistors R3 and R4 are connected in series between the junction of resistors R2 and R6 and the positive H.T. terminal. Resistors R3 and R4 constitute a potentiometer. The junction of resistors R3 and R4 is connected to the electrode 2 by way of the electrical connection 34, such that in operation of the device a trigger voltage, of for example, 500 V 5 KV is supplied to the control electrode 2. The junction between resistors R3 and R4 is connected to terminal D of a beam control unit, 51 which provides a low impedance path to the current flowing in to the beam control unit 51. Terminal B of the beam control unit 51 is connected to the positive H.T. terminal and a neon light and resistor 25 are connected in parallel between this terminal and terminal A which is connected to the plate 8 of the apparatus. neon light 53 connected in parallel with resistor R5 only conducts if the signal at terminal B exceeds a predetermined value. Thus the neon light acts as a short circuit to earth in the even of a current surge.

In operation of the apparatus of FIG. 2 gas, for example helium or argon is admitted to the chamber 7 by way of inlet duct 36 and is maintained at a predetermined pressure of a few microns in the chamber 7. The pressure is controlled or adjusted by controlling the rate of flow of gas into and out of the chamber. A trigger voltage is applied to the control electrode 2 by way of the electrical connection 34 and a negative potential of the order of 30 KV is applied to the cathode 21 to initiate a glow discharge which is insufficient to produce a useable electron beam. The dial 52 of the beam control unit 51 is turned to a predetermined position which selects a predetermined reference voltage. The current flowing in the electron beam is indicated by the current flowing through the resistor R5. The voltage produced by the current flowing through resistor R5 is subtracted from the reference voltage, and the signal representing the difference between the reference voltage and the voltage through resistor R5 is then amplified and employed to regulate the current to the control electrode (which flows through the diode gate 54) to control the degree of ionization in the gas and hence the power of the electron beam. A switch S1 is provided to enable the beam control unit to be rendered inoperative causing the beam to be turned off.

It is to be understood that the power at the trigger voltage is sufficient to initiate a glow discharge but is insufficient to produce a useful electron beam, and it is not until an appreciable current typically in the order of 10-100mA at a voltage of the order of 500 volts is applied to the control electrode 2 from the beam control unit 51 that the glow discharge is capa-

ble of producing a useful beam of electrons. The power of control electrode 2 at which the glow discharge is capable of producing a useful electron beam is dependent on many factors, for example the gas used, the pressure of the gas, the voltage applied to the cathode and the control electrode and geometric arrangement of the anode cathode 21 and the control electrode 2.

The electrode assembly 1 shown in FIGS. 1 and 2 is only two examples of arrangements of electrodes. It is to be understood that the anode, cathode and control electrode individually may be of any suitable shape and may be arranged in any suitable order such that when the appropriate voltage is applied to the anode and control electrode, an auxiliary glow discharge is generated and when a suitable voltage is applied to the cathode a main glow discharge results and an electron or ion beam is produced. The intensity of resulting electron or ion beam can be controlled by varying the potential applied to the control electrode 2.

An example of a different arrangement of electrodes is illustrated in FIG. 3. The electrode assembly 14 of FIG. 3 is similar to that disclosed in our co-pending British Pat. application Ser. No. 48,144/66 except for the provision of the control electrode 15, for initiating and/or augmenting a main glow discharge. The electrode assembly 14 consists of a cathode 16 having a portion 17 in the form of a curved metal plate and an anode 18 which has a mesh portion 19. By applying a negative potential to the control electrode 15 and earthing the anode 18 an auxiliary glow discharge may be generated. The auxiliary discharge may be used to initiate or augment a main glow discharge such that when a suitable negative potential is applied to the cathode a main glow discharge occurs and an electron beam results. By varying the potential applied to the control electrode 15 the glow discharge is varied and hence the intensity of the resulting electron beam is varied.

It is to be understood that the potentials applied to the anode and cathode may be reversed such that the anode 18 becomes a cathode and the cathode 16 becomes an anode, in which case an ion beam results instead of an electron beam when suitable potentials are applied to the anode and cathode. In the latter case the control electrode is positioned adjacent

to the anode such that by applying a suitable operating potential to the anode and control electrode, an auxiliary glow discharge may be generated. The auxiliary glow discharge may be used to initiate, control, or augment a main glow discharge such that an ion beam results.

It is to be understood that the operation of the devices of FIGS. 1, 2 and 3 are substantially the same. The only significant difference is in the shape and positioning of the anode, cathode and control electrodes. The operation of the control electrode 15 is the same as the control electrode 2.

The electrical circuit of the beam control unit 51 may be one of a number of well known feed back circuits which is capable of (a) producing a difference signal indicative of a difference between an input signal and a reference signal and (b) of amplifying the difference signal to provide an output signal which is representative of the difference signal.

We claim:

1. In a glow discharge device of the type in which an electron beam is produced by secondary electron emission from a surface of the cathode as the result of ion bombardment of the cathode, having an enclosure for containing an ionizable gas at a predetermined pressure, an anode, a cathode spaced from said anode, means for applying an electrical potential difference between said anode and cathode to ionize said gas and maintain a glow discharge, the improvement comprising a hollow control electrode of substantially annular shape having an open channel shaped cross-section facing inwardly, means for applying an electrical potential difference between the anode and said control electrode to further ionize said gas in the enclosure to a level at which the electron beam is produced by secondary emission from the cathode, said hollow control electrode being positioned where the electron beam emitted by the cathode passes through the hollow electrode.

2. A device according to claim 1 wherein a sensing means is provided to obtain a signal indicative of the current flowing in the said electron beam and means are provided to use said signal to vary the potential applied to the control electrode in response to said signal to modulate the power intensity of the beam.

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