United States Patent

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[33] **Great Britain**
[31] **33053/67**

[54] **COLD CATHODE DISCHARGE DEVICES**
9 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **315/111,** 219/121, 313/231
[51] **Int. Cl.** **H01j 37/04,** H01j 37/30
[50] **Field of Search** .... 315/111; 313/231; 219/121 (EB)

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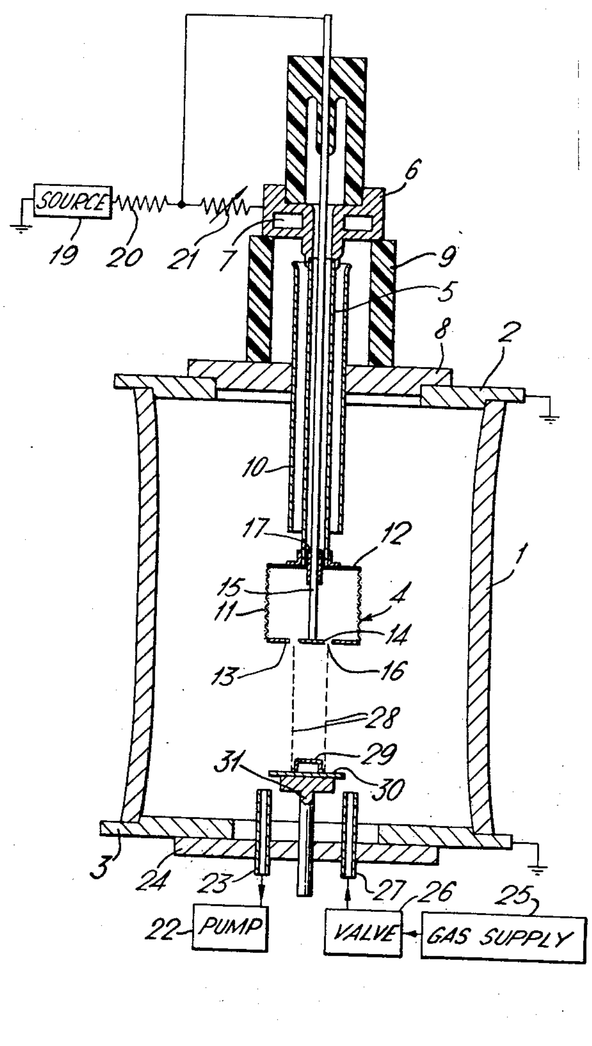
ABSTRACT: A cold cathode discharge device comprising an enclosure, having means to admit a gas to the interior of said enclosure and means to maintain the gas therein at a predetermined pressure. An anode is at least partly disposed within the enclosure and a hollow cathode of mesh material is mounted within the enclosure. One wall of the cathode has an aperture in which is positioned a further electrode which, with the aperture, defines a gap. A suitable operating potential is applied to the anode, cathode, and further electrode whereby a stream of electrons leave the hollow cathode through the gap to produce a beam having a cross-sectional shape substantially the same as the shape of the gap. The beam is focused by varying the potential applied to the further electrode.



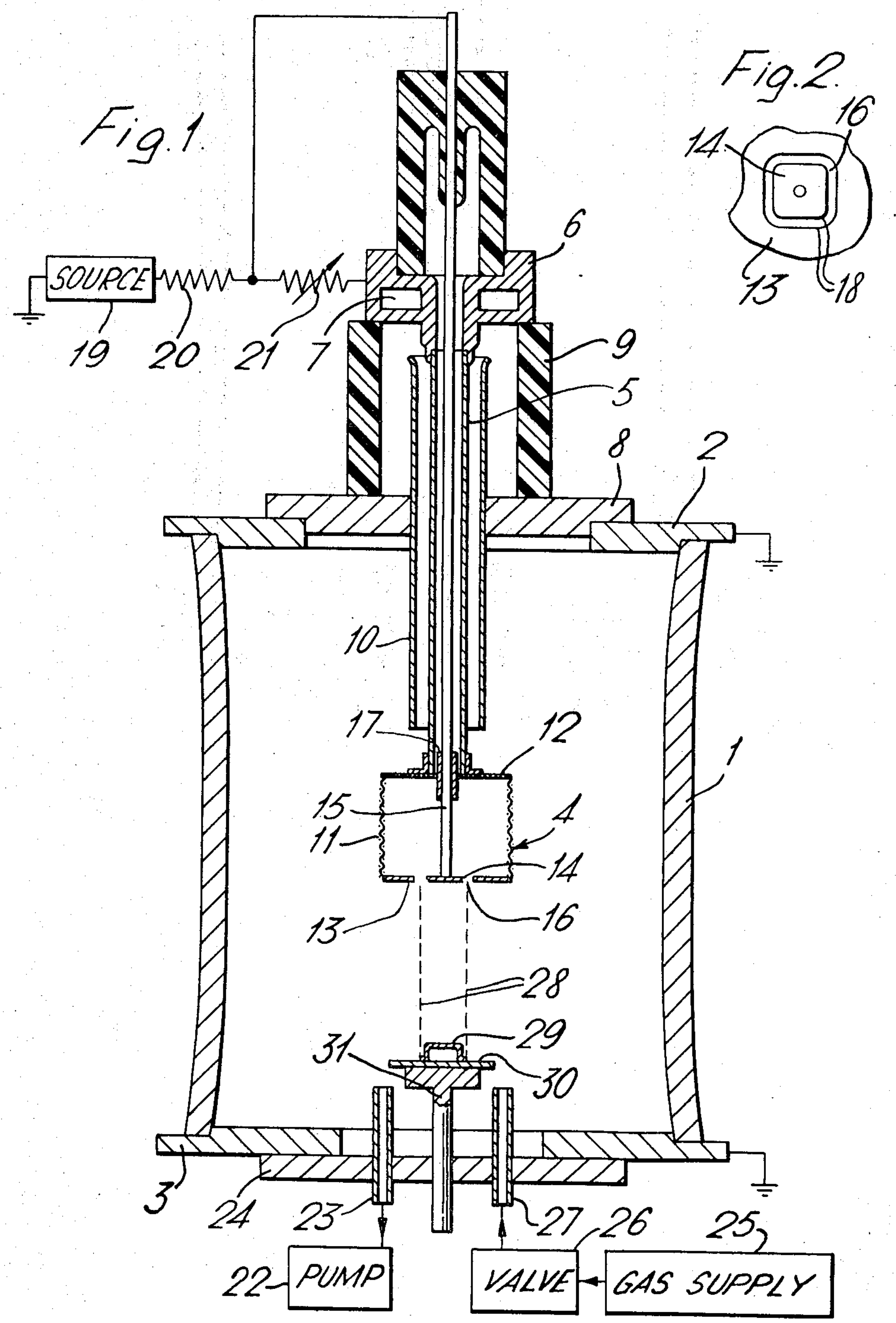
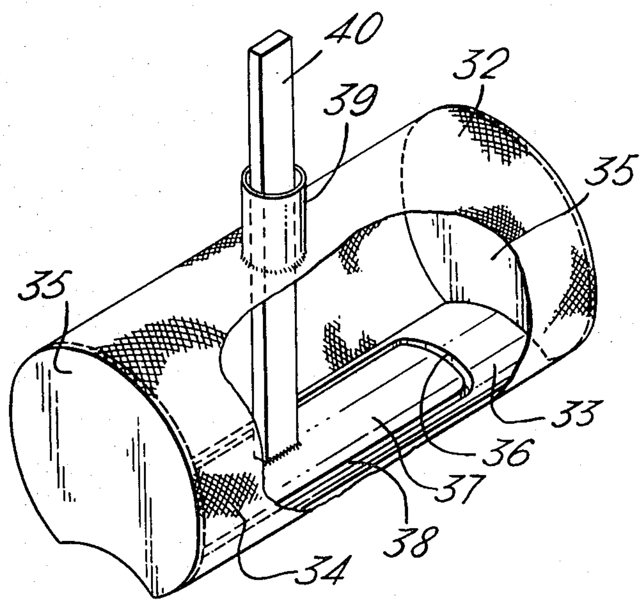


Fig. 1
SOURCE
19
20
21
7
6
9
5
8
2
10
17
12
15
11
4
14
1
13
16
28
29
31
30
3
24
23
27
26
25
22
PUMP
VALVE
GAS SUPPLY
Fig. 2
14
16
13
18

Fig. 3.



COLD CATHODE DISCHARGE DEVICES

This application is a continuation-in-part of application No. 605,452, filed Dec. 28, 1966, now U.S. Pat. No. 3,518,484.

This invention relates to cold-cathode discharge devices which form electron sources. The expression 'cold-cathode' as used in this specification signifies that the cathode is nonthermionic.

More particularly the invention relates an improvement in, or a modification to such devices as disclosed in the complete specification of our copending cognate British Pat. application Nos. 55206/65 and 12766/66. The cold-cathode discharge device disclosed in the above cognate patent applications comprises an enclosure, means to maintain the enclosure at a low gas pressure, an anode mounted within the enclosure or forming part of an interior wall of the enclosure, a hollow cathode formed at least partly of wire mesh mounted within the enclosure, one wall of the cathode being of circular outline and part spherical shape with the concave side outwards and having a central circular aperture, a further electrode of circular outline positioned in said aperture to define with said aperture an annular gap, and means to apply suitable operating potentials to the anode, cathode and further electrode. The resulting beam is of an annular cross-sectional shape and may be focused to impinge on an object over an annular region of the object or alternatively the beam may be brought to a point focus to impinge on the object at a small region.

With a circular aperture in the cathode and a circular plate or further electrode in the aperture to define the annular gap it is impossible to produce an elongated beam which may be focused to form a thin sheetlike beam of electrons or to subject an object to an electron beam over an area which is noncircular nor annular without scanning the beam.

An object of the present invention is to provide a cold cathode discharge device capable of producing an electron beam of a noncircular cross-sectional shape.

A further object of the present invention is to provide a cold-cathode discharge device capable of producing an electron beam which may be focused to from an elongated beam.

A further object of the present invention is to provide a cold cathode discharge device capable of subjecting an object to an electron beam over a noncircular or a nonannular shaped area of the object in one operation without scanning the electron beam.

According to the present invention, a cold-cathode discharge device comprises an enclosure, means to maintain the enclosure at a low gas pressure, an anode mounted within the enclosure or forming part of an interior wall of the enclosure, a hollow cathode formed at least partly of wire mesh mounted within the enclosure, one wall of the cathode having a central noncircular aperture, a further electrode of similar noncircular outline positioned in said aperture to define with said aperture a gap of substantially uniform width, and means to apply suitable operating potentials to the anode, cathode and further electrodes.

The operating potential applied to the further electrode may be the same as, or positive relative to, or negative relative to, that applied to the cathode.

The cathode may be of a cylindrical shape with the said aperture provided in an end wall of the cylindrical shape. The end wall may be concave outwardly with respect to the cathode if desired.

Alternatively the cathode may be of a cylindrical shape with the said aperture provided in a longitudinal wall of the cylindrical shape. Preferably the aperture in the longitudinal wall of the cylindrical shape is provided in a portion of the wall which is concave outwardly with respect to the cathode.

The cathode need not be of a right circular cylindrical shape but may be of any desired cross-sectional shape, for example, it may be rectangular.

An earthed screening electrode may be provided to encompass part of said cathode if desired.

A cold-cathode discharge device in accordance with the present invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 shows a partly diagrammatic section through the device;

FIG. 2 shows an underneath plan view of a part of the device of FIG. 1; and

FIG. 3 shows a modified form of the cathode shown in FIG. 1.

Referring to FIG. 1, the device comprises an enclosure formed by an approximately cylindrical tube 1 of heat resisting glass, about 22 cms. in diameter and 30 cms. long, closed at the ends by aluminum plates 2 and 3 with O-ring seals (not shown), and supported with its axis vertical. The plates 2 and 3 are both earthed, and in operation of the device form anodes.

A cathode 4 is supported within the enclosure by a conducting tube 5 which extends downwards from a cathode connector 6 having a bore 7 for water cooling. The cathode connector 6 is secured to a removable portion 8 of the plate 2 by way of an insulating cylinder 9. Extending through the portion 8, concentric with the tube 5, is a conducting tube 10 which forms an earthed shield.

The cathode 4 comprises a right circular cylindrical portion 11 with flat portions 12 and 13 at the top and bottom respectively. The portion 13 of the cathode 4 has a central noncircular aperture. A flat plate of similar noncircular outline which forms a further electrode 14 is supported in the aperture in the portion 13 of the cathode 4 by a conducting rod 15, so as to leave a gap 16 of uniform width between the electrode 14 and the portion 13. The rod 15 passes through an insulating bush 17 in the portion 12 of the cathode 4.

Referring to FIG. 2, the gap 16 is, in the particular embodiment of the device here described, of approximately square shape. The edge of the aperture in the portion 13 of the cathode 4 and the edge of the further electrode 14 are rounded at the corners 17 so that the gap 16 is of substantially uniform width throughout. In some cases small alumina pegs may be pushed into the gap 16 at intervals around it for the purpose of maintaining the width uniform.

Referring again to FIG. 1, the portion 11 of the cathode 4 is of stainless steel mesh or refractory wire mesh, and the portions 12 and 13, and the electrode 14 are of refractory metal plate, for example, tantalum plate. Alternatively, the portion 13 and the electrode 14 may also be formed of stainless steel mesh or refractory wire mesh. In this case the edges of the portion 13 and the electrode 14 defining the gap 16 may be made smooth by welding to them rings of the appropriate shape.

The rod 15 is of a refractory metal, although alternatively the rod 15 may be replaced by a support formed by a cylinder of stainless steel wire mesh, this alternative being possible because of the reduced heating effect on a mesh.

Power is derived from a source 19 comprising an autotransformer which supplies a variable voltage to the primary winding of a high voltage transformer, the output of which is rectified by a full wave rectifier. The connection to the cathode connector 6 is by way of resistors 20 and 21 in series, the resistor 21 being variable. The junction of resistors 20 and 21 is connected to the rod 15. The circuit also includes an ammeter and a voltmeter (not shown).

Evacuation of the enclosure is by means of an oil diffusion pump 22 backed by a rotary pump (not shown), connection to the pumps being by way of an outlet pipe 23 passing through a removable portion 24 of the plate 3. To measure the pressure a pirani gauge (not shown) is connected to the outlet pipe 23 immediately outside the enclosure. A gas is supplied from a gas supply cylinder 25 through a two-stage pressure regulator and a needle valve 26 to an inlet pipe 27 which also passes through the portion 24 of the plate 3. The pressure in the enclosure is controlled by adjusting the flow of gas with the pumps working continuously.

There are several ways in which the device may be operated, some of which will now be described.

In the first case the enclosure is evacuated to a pressure of approximately 5×10^{-3} with helium to a pressure of approximately 3×10^{-2} torr. A negative potential of approximately

2.75 kilovolts is applied to the cathode 4, the resistor 21 being set to zero, so that the same potential is applied to the electrode 14 as to the cathode 4. When outgassing of the cathode 4 has occurred, the helium pressure is allowed to rise slowly. This is done by adjustment of the valve 26.

A hollow cathode discharge develops, accompanied by a stream of electrons which passes through the gap 16. Due to the shape of the gap 16 the stream of electrons forms a beam 28 of hollow square cross section.

The beam 28 is particularly adapted for a welding operation in which the edges of a square metallic cap 29 are to be welded to a metallic base 30. The cap 29 may form part of a can for a semiconductor device. To perform the welding operation the base 30 is mounted on a metallic support 31 and is so connected as an anode. On directing the beam 28 at the cap 29 the whole of the edge of the cap 29 is welded in one operation without the need to move the cap 29 or cause the beam 28 to scan.

In the second case the operation is generally similar except that the gas used is argon, in which case the pressure to which the enclosure is initially evacuated and the operating pressures are lower. The resistor 21 is set to a low value, so that the electrode 14 is at a negative potential relative to the cathode 4. A beam 28 is obtained with the cathode 4 at a negative potential of 6 kilovolts and an argon pressure of 10^{-2} torr.

In the third case the enclosure is evacuated and filled with helium as in the first case. With a helium pressure of 18×10^{-2} torr, the resistor 21 set to zero, and a negative potential of approximately 2.75 kilovolts applied to the cathode 4 a glow discharge occurs. This is not accompanied by an electron beam and the result of the discharge is that the potential difference between the support 31 and the cathode 4 falls to approximately 300 volts.

On raising the value of the resistor 21 to approximately 1,800 ohms the glow discharge is restricted. This manner of operation thus demonstrates that varying the potential of the electrode 14 relative to the cathode 4 can be used to restrict and therefore control a glow discharge which would otherwise occur under certain operation conditions. This can prolong the life of the cathode 4 by reducing heating, and also makes it possible to pulse the electron beam on and off for the purpose of performing a welding operation.

The device may be operated with other gases, for example, oxygen. In this case, however, it is desirable, although not essential, to make the cathode 4 of an oxidation resistant material.

The device may be used for various other purposes, such as heat treatment, melting or zone refinement, in which heating, particularly the heating of a refractory material, is involved.

Depending on the use to which the device is to be put, some modifications or additional features may be possible or desirable.

One modification to the cathode 4 shown in FIG. 1 is illustrated in FIG. 3 which shows a cathode 32 as a generally right circular cylindrical shape having a portion 33 formed by a longitudinally extending indentation. The cathode 32 is arranged in an enclosure similar to the enclosure shown in FIG. 1 such that the longitudinal axis of the cylindrical shape lies in a substantially horizontal plane. It may be necessary to modify the shape of the enclosure 1 of FIG. 1 to accommodate the cathode 32.

The curved surface 34 of the cathode 32 is made of a mesh or perforated material such as for example tantalum, and the portion 33 is made from mesh material or perforated material or thin solid plate material such as for example stainless steel, or tantalum or other refractory metal. The end plates 35 of the cathode 32 are made from thin sheet metal for example stainless steel tantalum or other refractory metal. The portion 33 of the cathode 32 is provided with a noncircular aperture 36. Positioned in or adjacent the aperture is a further electrode 37 which with the aperture 36 defines a gap 38. The cathode 32 may be attached to the tube 5 of FIG. 1 by means of a thin tubular boss 39 which is tack welded on to cathode 32. The further electrode 37 is connected to the power supply by way of the connector 40.

It is to be understood that the mode of operation of the cathode 32 and further electrode 37 is identical to that of the cathode 4 and further electrode of FIG. 1, and the potentials applied to the cathode 32 and further electrode 3 may be the same as that described above. The only significant difference between the structure shown in FIG. 3 and the cathode 4 and further electrode 14 of FIG. 1 is in the shape and construction of the cathode and further electrode.

It is to be understood that the gaps defined by the cathodes 4 and 32 and the further electrodes 14 and 37 may be of any desired shape to produce a hollow electron beam of any desired cross-sectional shape, for example of a substantially rectangular shape, an eliptical shape, an ogival shape a multi sided shape or an irregular shape. The hollow beam may be brought to a point focus if desired or arranged to focus along a line.

In some circumstances it may be preferable, to provide a separate power supply for the electrodes 14 or 37 so that they can be maintained at a positive or a negative potential relative to the cathode 4 or 32. In either case the glow discharge can be restricted if the potential relative to the cathode 4 is made large enough.

An earthed screening electrode may be arranged to encircle the cathode 4 to reduce the loss of electrons to the walls of the enclosure.

I claim:

1. A cold-cathode discharge device comprising an enclosure, means to admit a gas to the interior of said enclosure, and means to maintain the gas therein at a predetermined pressure, an anode at least partly disposed within the enclosure, a hollow cathode formed at least partly of a mesh material mounted within the enclosure, one wall of said cathode having a substantially rectangular aperture therein, a further electrode of a similar substantially rectangular outline to said aperture positioned in said aperture to define with said aperture a gap, and means to apply suitable operating potentials to the anode, cathode and further electrode.

2. A device as claimed in claim 1 wherein the cathode is of a cylindrical shape and the said aperture is provided in an end wall of the said cathode.

3. A device as claimed in claim 1 wherein the cathode is of a cylindrical shape and the said aperture is provided in the longitudinal sidewall of said cathode.

4. A device as claimed in claim 1 wherein the cathode is of a cylindrical shape with a longitudinally extending indentation portion in the longitudinal wall of the cathode, said indentation being such as to present a concave surface outwardly with respect to the said cathode, and said aperture being provided in said indentation portion.

5. A device as claimed in claim 1 wherein said cathode is substantially right circular cylindrical.

6. A device as claimed in claim 1 wherein an earthed screening electrode is provided to encompass part of said cathode.

7. A device as claimed in claim 1 wherein the operating potential applied to said further electrode is the same as that applied to the cathode.

8. A device as claimed in claim 1 wherein the operating potential applied to said further electrode is negative with respect to said cathode.

9. A device as claimed in claim 1 wherein the operating potential applied to said further electrode is positive with respect to said cathode.