

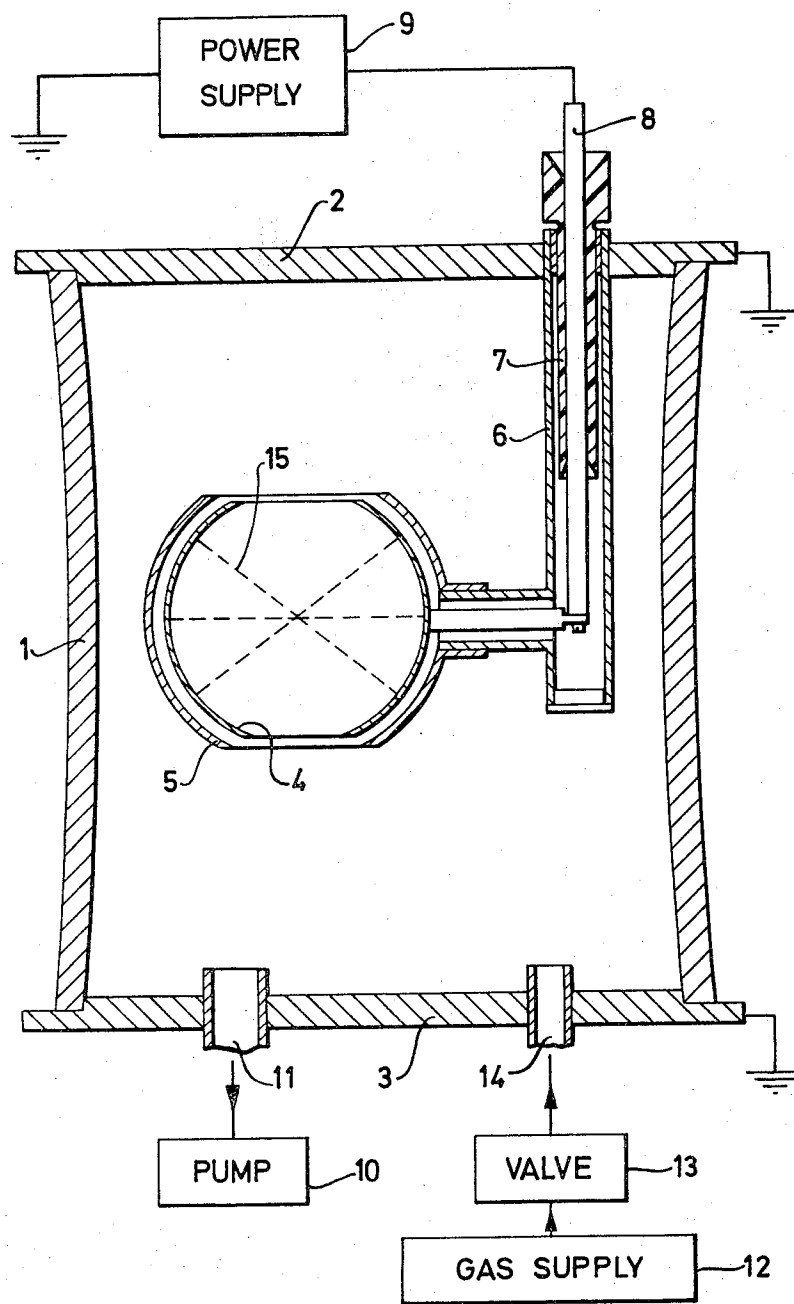
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NONTHERMIONIC HOLLOW CATHODE DISCHARGE DEVICES

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NONTHERMIONIC HOLLOW CATHODE DISCHARGE DEVICES

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2 Claims. (Cl. 313—231)

ABSTRACT OF THE DISCLOSURE

A nonthermionic hollow cathode discharge device comprising an enclosure, means to maintain the enclosure at a low gas pressure, an anode mounted with at least one surface thereof within the enclosure, a hollow cathode mounted within the enclosure, the cathode comprising a portion in the shape of a hollow sphere truncated by two parallel planes symmetrically disposed about the centre of the sphere, a perforated shielding electrode of generally similar shape to the cathode which surrounds the cathode, the spacing between the cathode and the shielding electrode being uniform and sufficiently small for no appreciable discharge to take place between them during operation, and means to apply suitable operating potentials to the anode, cathode and shielding electrode, substantially the same potential being applied to the anode and the shielding electrode, the arrangement being such that during operation a glow discharge occurs and streams of electrons converge in the region of the centre of a space generally defined by said hollow.

This invention relates to cold cathode, glow discharge devices and more particularly to such devices which form electron sources.

Such devices can be used, for example, for the heat treatment, welding, melting or zone refinement of refractory materials.

According to the present invention, a cold cathode, glow 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 mounted within the enclosure, the cathode comprising a portion in the shape of a hollow sphere truncated by two parallel planes symmetrically disposed about the centre of the sphere, a perforated shielding electrode of generally similar shape to the cathode which surrounds the cathode, the spacing between the cathode and the shielding electrode being uniform and sufficiently small for no appreciable discharge to take place between them during operation, and means to apply suitable operating potentials to the anode, cathode and shielding electrode, substantially the same potential being applied to the anode and the shielding electrode, the arrangement being such that during operation a glow discharge occurs and streams of electrons converge in the region of the centre of a space generally defined by said hollow cathode.

A cold cathode, glow discharge device in accordance with the present invention will now be described by way of example with reference to the accompanying drawing, which shows the device partly diagrammatically and partly in section.

Referring now to the drawing, the device comprises an enclosure formed by a cylindrical tube 1 of heat resisting glass, approximately 23 cm. in diameter and 30 cm. long, closed at the ends by aluminum plates 2 and 3 with O-ring seals (not shown), and supported with its axis vertical. The end plates 2 and 3 are earthed and in operation of the device form anodes.

Within the enclosure are mounted a cathode 4 and a shielding electrode 5. The cathode 4 is formed of stainless steel plate and is in the shape of a hollow sphere about 8 cm. in diameter which is truncated by two planes symmetrically disposed about the centre of the sphere and both parallel to the anodes 2 and 3. The spacing between these planes is about 6 cm. The shielding electrode 5, which is formed of stainless steel wire mesh, is of generally similar shape to the cathode 4, but is slightly larger so that it surrounds the cathode 4. The spacing between the cathode 4 and the shielding electrode 5 is uniform and sufficiently small (about 6 mm.) for no appreciable discharge to take place between them during operation.

The shielding electrode 5 is supported by a tube 6 of electrically-conducting material which serves also to maintain the shielding electrode 5 at the same potential as the anodes 2 and 3 during operation. Within the tube 6 is a tube 7 of electrically-insulating material and within this a rod 8 of electrically-conducting material which serves as a support for, and an electrical connection to, the cathode 4.

A power supply 9 is arranged to maintain the potential of the cathode 4 at a value variable over the range 500 volts to 3 kilovolts negative, and to supply a current of up to 1 amp. The supply arrangement includes an ammeter and a voltmeter, and means to limit the current (not shown).

Evacuation of the enclosure is by means of a rotary pump 10, connection to the pump 10 being by way of an outlet pipe 11 passing through the anode 3. Hydrogen is supplied from a gas supply cylinder 12 through a regulator (not shown) and a valve 13 to an inlet pipe 14 which also passes through the anode 3. The device will operate with other gases, but hydrogen is favoured because of the low sputtering of the cathode 4 which it causes. This is particularly important where contamination of the specimen being heated is to be kept to a minimum, for example, in zone refining. If necessary, sputtering can be reduced still further by using a low sputtering metal, such as tungsten or molybdenum for the cathode 4. The pressure in the enclosure is controlled by adjusting the valve 13 so as to vary the flow of hydrogen, the pump 10 working continuously.

The device is operated in the following way. The enclosure is evacuated to a pressure of approximately 10^{-3} torr and then filled with hydrogen to a pressure of approximately 0.5 torr, this pressure being maintained by adjusting the valve 13 so that the gas flow balances the capacity of the pump 10. The cathode 4 is then brought to such a potential that a glow discharge forms in which the anode plasma penetrates inside the cathode 4, no discharge taking place between the outside of the cathode 4 and the shielding electrode 5. The discharge required within the cathode 4 is one in which a dark space occurs concentric with the cathode 4, the thickness of this dark space depending upon the operating conditions. This dark space represents the cathode fall and most of the applied voltage appears across it. Thus, the electric field lines are all perpendicular to the inner surface of the cathode 4, and fast electrons crossing the cathode fall are directed towards the hollow central region of the cathode 4 as indicated by the broken lines 15. Any material placed at the centre of the sphere is therefore heated by the kinetic energy of the fast electrons. As the material is immersed in the plasma no electrical charging can occur and electrically-insulated materials, as well as metals, can be heated.

To avoid glow to arc transitions during the initial stages of operation when the cathode 4 is cold, it is desirable to preheat the cathode 4 to about 200° C. This may conveniently be achieved by focusing radiant heat onto the cathode 4 from a source outside the tube 1, or it may be

achieved by the attachment to the cathode 4, or the shielding electrode 5, of an electrical resistance heater.

To use the device, the material which it is desired to heat is arranged to be mounted within the axially extending aperture in the cathode 4. For example, where a rod of refractory material is to be zone refined, the rod is held in a holder which is mounted on a screw thread operable from outside the enclosure so that the rod can be moved longitudinally through the central region of the cathode 4 where the maximum heating occurs. The temperature in this region can be made high enough to melt a 0.3 mm. diameter rod of tungsten.

The device may of course be used for other purposes, such as heat treatment, welding or melting, in which heating, particularly the heating of a refractory material, is involved. One such purpose is in the growing of single crystals of a material from a multicrystalline rod of the material by passing a melted zone along the rod, the material recrystallising as a single crystal on solidification.

In some cases some preheating and/or slower cooling of a material may be required. This can be achieved by adding right circular cylindrical or conical portions to the top and/or bottom of the cathode 4 and shielding electrode 5. Each such portion has its axis vertical and where it abuts the opening in the cathode 4 has the same diameter as the opening. During operation streams of electrons are produced within these portions and converge on the axes. This provides additional heating, although it is less intense than that in the hollow central region of the cathode 4.

I claim:

1. A cold cathode, glow discharge device comprising an enclosure, means to maintain the enclosure at a low gas pressure, an anode mounted with at least one surface thereof within the enclosure, a hollow cathode mounted within the enclosure, the cathode comprising a portion in the shape of a hollow sphere truncated by two parallel planes symmetrically disposed about the centre of the sphere, a perforated shielding electrode of generally similar shape to the cathode which surrounds the cathode, the spacing between the cathode and the shielding electrode being uniform and sufficiently small for no appreciable discharge to take place between them during operation, and means to apply suitable operating potentials to the anode, cathode and shielding electrode, substantially the same potential being applied to the anode and the shielding electrode, the arrangement being such that during operation a glow discharge occurs and streams of electrons converge in the region of the center of a space generally defined by said hollow cathode.

2. A device in accordance with claim 1 wherein the cathode is formed of stainless steel plate and the shielding electrode is formed of stainless steel wire mesh.

References Cited

UNITED STATES PATENTS

3,262,003	7/1966	Allen et al.	313—187 X
3,320,475	5/1967	Boring	313—231 X

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