

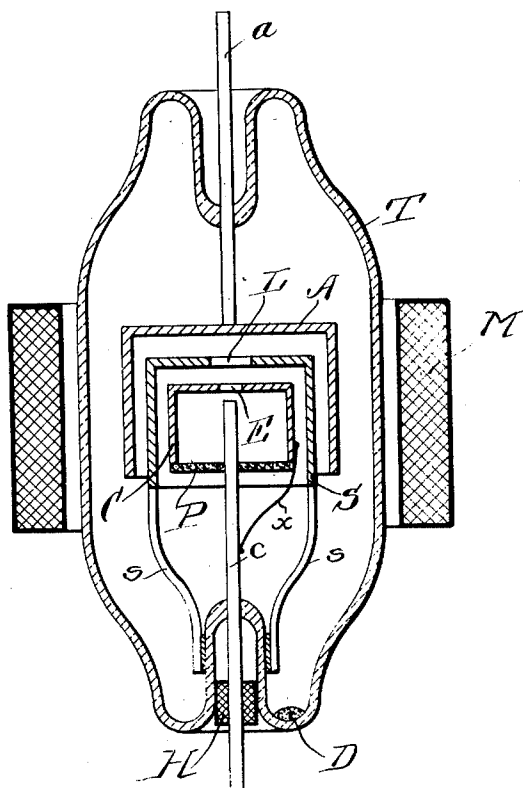
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ELECTRIC DEVICE

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UNITED STATES PATENT OFFICE

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ELECTRIC DEVICE

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12 Claims. (Cl. 250—27.5)

This invention relates to gaseous discharge devices in which ionization is a substantial factor and in which the current density is substantially in excess of that in a glow discharge device. My invention is particularly applicable for use as rectifiers.

Particular objects of the invention are to pass current at a low potential difference between cathode and anode, to avoid excessive heating of the electrodes and associated parts by the cathode-anode current, to produce ample electronic emission from the cathode, to direct the electronic discharge to the anode with minimum resistance, to avoid the necessity of using large quantities of vapor yielding material, to prevent electronic conduction from anode to cathode in response to reverse potential as in rectifying, and in some cases to eliminate the space charge in the region of the anode.

In one aspect the invention comprises a low pressure or high vacuum tube (of the order of .01 mm. of mercury e. g.) containing a cathode having a much higher pressure (of the order of .1 mm. of mercury e. g.) maintained in the region of its discharge surface by electric forces (electrostatic or magnetic or both) for the purpose of obtaining ample electronic emission. This difference of pressure is maintained by an obstruction between the electron source and the electron receiving area, the obstruction having an opening therethrough for the passage of electrons and the opening being so restricted that a difference of pressure (or state of ionization) may be maintained on opposite sides of the obstruction. As will appear hereinafter the obstruction is preferably formed as a part of the cathode. According to the present invention the aforesaid difference in pressure may be maintained by centrifugal action, preferably produced by a magnetic field extending longitudinally of the axis of said opening, the field reacting with the electric discharge to whirl the molecules (or atoms) of gas and build up a higher pressure near the inner periphery of the hollow cathode.

In another aspect the invention involves the use of gases having different facility of ionization or ionization voltages and the maintenance of a higher proportion of the more ionizable gas in the region of the electron source (e. g. inside the hollow cathode) than in the region of the anode or other electron receiving region. This is preferably accomplished by means of a porous or semi-permeable wall or membrane, formed for example of carbon or quartz, or metal with holes small enough to restrict the gaseous transfer to

the type known as pure diffusion, through which the less ionizable gas may escape from the cathode (preferably solely by the phenomenon of diffusion) without permitting the more ionizable gas to escape so readily or at all. For example, by using a mixture of helium and mercury vapor with a quartz wall, the helium escapes while the more ionizable mercury vapor can not pass through the quartz wall and therefore accumulates in the cathode. Inasmuch as helium has a diffusion rate more than seven times that of mercury vapor the pressure of mercury vapor inside the cathode can be caused to preponderate greatly over its pressure outside the cathode even when using a porous wall of carbon which will pass the mercury vapor to some extent. For certain classes of work the vacuum tube may be filled with helium to a pressure of the order of one-half centimeter of mercury and a small quantity of mercury (as little as a single drop in small tubes) may be incorporated in the tube to supply the mercury vapor. The ionization voltages of mercury and helium are ten and one-half volts and twenty-five volts respectively.

Thus the gas in the cathode may be more intensely ionized and thereby afford a lower voltage drop between the electrodes. The effect may be accentuated by intensely heating the gas in the cathode (e. g. 2800° C. or higher) as disclosed for example in my copending application Serial No. 13,145 filed on even date herewith and in Serial No. 696,337 filed March 1, 1924. With the gas inside the cathode at high temperature many of the atoms are in an excited state, that is their electrons are displaced from their orbits near the atomic nuclei to more remote orbits without being entirely removed from the influence of the nuclei, and consequently electrons flowing from the inner surface of the cathode readily ionize the gas in the cathode. Thus the voltage drop is reduced to a low value.

While other gases having different ionizing and diffusing characteristics offer the same general advantages (e. g. hydrogen may be used instead of helium and caesium vapor, krypton or xenon may be used instead of mercury vapor) the above combination of gases offers special advantages. For example, helium offers a long mean free path as disclosed in Serial No. 464,358 now Patented No. 1,617,174 granted February 8, 1927 and mercury may be incorporated in liquid form thus insuring practically an inexhaustible supply of vapor.

In still another aspect the invention involves shielding the anode from positive ion bombard-

ment during the portion of the cycle in which the current to the anode is small (e. g. in a rectifying tube, during the half-cycle in which the anode is negative), whereby the gaseous discharge between the electrodes is more effectively restricted to one direction in starting with the cathode cold, the helium shielding the anode from excessive bombardment by mercury ions during the half-cycles of reverse voltage.

The invention is particularly applicable to the rectification of alternating current and rectifiers incorporating the invention are characterized by low voltage drop even when rectifying current of moderately high voltage, (e. g. one thousand volts and upward). For the purpose of illustration the invention is shown as applied to a rectifier in the accompanying drawing in which the figure represents, more or less diagrammatically, a longitudinal axial section of a rectifying tube comprising an anode A, a cathode C, a shield S, a tube T and an electro-magnet M encircling the tube. The aforesaid parts are preferably cylindrical in transverse section and coaxial. The tube T may be formed of hard or highly refractory glass and the electrodes A and C and the shield S of tungsten or other suitable material; and the electrodes and shield may be supported in the tube by any suitable means, stems a, c, and s being shown for that purpose. The anode A substantially encloses the cathode C and shield S and prevents radiations and materials from escaping from the space so enclosed. D represents a drop of mercury or other vapor yielding material for supplying, either by normal evaporation or by application of external heat (e. g. with a heating coil H), one of the aforesaid gases. When employing helium at approximately one-half centimeter pressure a drop of mercury will afford a suitable proportion of mercury vapor in the tube. P designates the porous or semi-permeable membrane or wall hereinbefore referred to. In the event membrane P comprises quartz or other insulating material, a conductor X is necessary between cathode C and stem c; this lead is desirable, though not necessary, in case member P is a semi-conductor, as carbon. When using helium and mercury this wall is preferably formed of quartz, to permit the diffusion of helium therethrough without passing the mercury vapor, and it may be anchored over the lower end of the hollow cathode C in any suitable manner.

With a suitable potential impressed between the cathode C and anode A an electron stream flows from the interior of the hollow cathode through openings E and L to the anode, the shield S serving to localize the heat produced in the cathode by the current flow and thereby augmenting ionization within the cathode as described in the aforesaid copending applications. The shield S also serves to localize the current flow along a restricted path. Thus all the discharges which occur are confined and pass from the interior of the cathode C through the openings E and L to the anode A. When the magnet M is energized the field thereby produced reacts with the field produced by said current, thereby rotating the gas inside the cathode. This rotation of the gas produces a higher pressure adjacent the inner periphery of the cathode, thereby affording a higher state of ionization at the active surface of the cathode and facilitating electronic emission therefrom. By extending the stem c through the center of the cathode to a point adjacent the opening E, the gas inside

the cathode is more effectively trapped and prevented from flowing out of the cathode along the axis thereof. Indeed this construction results in gas flow into the cathode through opening E, which is in the nature of a continuous pumping action, thereby maintaining a higher average pressure inside the cathode than outside.

Owing to the fact that the less ionizable gas (e. g. helium) diffuses through the well P the gas trapped in the hollow cathode is predominantly the more ionizable component (e. g. mercury vapor), thereby further favoring current flow from the interior of the cathode. When the more ionizable gas is also heavier than the less ionizable gas (as mercury vapor is heavier than helium) the preponderance of the more ionizable gas adjacent the inner periphery of the hollow cathode is further augmented by the aforesaid centrifugal action.

The combined effect of the aforesaid factors, conducing to a high state of ionization inside the cathode, is to make the interior of the hollow cathode a markedly effective source of electrons as disclosed in my copending application Serial No. 13,145 filed herewith. This effect may be further accentuated by heating the cathode independently of the current flow between cathode and anode or by coating the interior surface of the cathode with a high electron emitting material such as caesium, whereby copious electron emission is produced at the temperature at which the cathode surface is maintained. This coating gives the interior surface of the cathode a low work function as compared with the higher work function of the anode surface. The cathode may also be maintained at a higher temperature by making its outer surface or the inner surface of the shield S highly reflecting or both. By making the inner surface of the cathode bright less light is absorbed by the cathode and ionization inside the cathode is further augmented.

For some purposes the present invention may advantageously incorporate the mean free path principle disclosed in my prior applications Serial Nos. 406,886, 415,536, 526,095 etc., now Patent No. 1,545,207, granted July 7, 1925 and Patents No. 1,617,171 and No. 1,617,179, granted February 8, 1927 in which case the distance between cathode C and shield S or between shield S and anode A or both should be confined substantially to the mean free path of electrons in the gas in these spaces, that is, the average distance traveled by an electron at ionizing velocity without ionizing impact with a gas molecule.

From the foregoing it is evident that the top portion of the cathode surrounding the opening E constitutes an obstruction between the electron emitting periphery of the cathode and the electron receiving surface of the anode, and restricts the current flow to the opening E.

The features of invention relating to the mounting of the shield around the anode and the spacing between the shield and the adjacent electrodes are not claimed in this application, but in my co-pending applications Serial No. 55,262, filed September 9, 1925, and Serial No. 76,792, filed December 21, 1925, which are as to these features continuations of the present application. The features of invention relating broadly to the use of two gases having different ionizing voltages, and the maintenance of the gas having a lower ionization voltage at higher density adjacent the cathode surface than in the anode

region, are likewise not claimed in the present application, but are made the subject matter of my co-pending application Serial No. 55,262, filed September 9, 1925, which is in this respect a continuation of the present application.

I claim:

1. A gaseous discharge device comprising a tube containing an easily ionizable gas and a gas less easily ionizable but more diffusible, an anode, a hollow cathode having a discharge opening therein, said cathode having an obstructed passageway through which the less easily ionizable gas may escape more rapidly than the other gas, whereby when a discharge occurs, said gases will be pumped into the hollow cathode and allow the less easily ionizable gas to escape.

2. A gaseous discharge device comprising a tube containing an easily ionizable gas and a gas less easily ionizable but more diffusible, an anode, a hollow cathode having a discharge opening therein, said cathode having a porous wall through which the latter gas may escape more readily whereby when the discharge occurs, said gases are pumped into the cathode permitting the less easily ionizable gas to escape.

3. A unidirectional space current discharge device comprising an evacuated envelope containing a gas, a portion of which is more ionized during discharge than another portion of it, an anode, a cathode structure having a discharge surface and constituting an enclosure confining a body of gas in said envelope adjacent said discharge surface, said enclosure having an opening for passing the discharge to said anode and having portions more permeable to the gas portion that is not ionized than to the gas portion that is ionized.

4. A unidirectional space current discharge device comprising an evacuated envelope containing a filling of easily ionizable gas and a difficult-to-ionize gas, an anode, a cathode structure having a discharge surface and constituting an enclosure confining a body of said gas filling in said envelope adjacent said discharge surface, said enclosure having an opening for passing the discharge to said anode, said enclosure having a portion opposing outflow of said easily ionizable gas more than said difficult-to-ionize gas.

5. A unidirectional space current discharge device comprising an evacuated envelope containing a gas filling composed of a mixture of different gases, an anode, a cathode having a discharge surface and constituting an enclosure confining a body of said gas filling in said envelope adjacent said discharge surface, said enclosure having an opening for passing the discharge to said anode, said enclosure having portions of different degrees of permeability for the different gases of said mixture.

6. A space current discharge device comprising an evacuated envelope containing a gas, a portion of which is more ionized during the discharge than another portion of it, an anode, and a cathode within said envelope, an enclosure constituting a confinement around a part of the discharge path between said cathode and said anode, and means adjacent to said enclosure to produce movement of gas into said enclosure during a discharge, said enclosure having a portion of different permeability to the portion that is more ionized than to the gas portion that is less ionized.

7. A space discharge device comprising a gas-tight envelope containing an ionizable atmosphere, an anode, and a cathode which during operation is maintained at an elevated temperature to give copious electron emission, said cathode and anode being adapted to support an ionizing discharge between them, said cathode comprising an electron emitting surface adapted to be heated to a temperature of copious electron emission, and a hollow member surrounding said emitting surface, an opening of substantial size in said hollow member, said anode having a surface of relatively high work function substantially closing said opening to prevent radiations and material liberated by the discharge from escaping from the space enclosed by said hollow member and said anode, said anode being insulated from said hollow member, all of the discharges which occur in said device being confined to the space enclosed by said hollow member and anode.

8. A space discharge device comprising a gas-tight envelope containing an ionizable atmosphere, an anode, and a cathode which during operation is maintained at an elevated temperature to give copious electron emission, said cathode and anode being adapted to support an ionizing discharge between them, said cathode comprising an electron-emitting surface adapted to be heated to a temperature of copious electron emission, and a hollow conducting member electrically connected to and surrounding said emitting surface, and an opening of substantial size in said hollow member, said anode having a surface of relatively high work function substantially closing said opening to prevent radiations and material liberated by the discharge from escaping from the space enclosed by said hollow member and said anode, all of the discharges which occur in said device being confined to the space enclosed by said hollow member and anode.

9. A space discharge device comprising a gas-tight envelope containing an ionizable atmosphere, an anode, and a cathode which during operation is maintained at an elevated temperature to give copious electron emission, said cathode and anode being adapted to support an ionizing discharge between them, said cathode comprising an electron-emitting surface adapted to be heated to a temperature of copious electron emission, and a hollow conducting member electrically connected to and surrounding said emitting surface, and an opening of substantial size in said hollow member, said anode having a surface of relatively high work function substantially closing said opening to prevent radiations and material liberated by the discharge from escaping from the space enclosed by said hollow member and said anode, all of the discharges which occur in said device being confined to the space enclosed by said hollow member and anode.

10. A space discharge device comprising a gas-tight envelope containing an ionizable atmosphere, an anode, and a cathode which during operation is maintained at an elevated temperature to give copious electron emission, said cathode and anode being adapted to support an ionizing discharge between them, said cathode comprising an electron-emitting surface adapted to be heated to a temperature of copious electron emission, and a hollow conducting member electrically connected to and surrounding said emitting surface, and an opening of substantial size in said hollow member, said anode having a surface of relatively high work function substantially closing said opening to prevent radiations and material liberated by the discharge from escaping from the space enclosed by said hollow member and said anode, said anode also having a relatively large area exposed to the atmosphere outside of the space enclosed by said hollow conducting member and said anode, all of the discharges which occur in said device being confined to the space enclosed by said hollow member and anode.

11. A space discharge device comprising a gas-tight envelope containing an ionizable atmosphere, an anode, and a cathode which during operation is maintained at an elevated temperature to give copious electron emission, said cathode and anode being adapted to support an ionizing discharge between them, said cathode comprising an electron-emitting surface adapted to be heated to a temperature of copious electron emission, and a hollow conducting member electrically connected to and surrounding said emitting surface, an opening in said hollow member, said anode having a surface substantially blocking

said opening to prevent radiations and material liberated by the discharge from escaping from the space enclosed by said hollow member and said anode.

- 5 11. A space discharge device comprising a gas-tight envelope containing an ionizable atmosphere, an anode and a cathode which during operation is maintained at an elevated temperature to give copious electron emission, said cathode
10 comprising an electron-emitting surface adapted to be heated to a temperature of copious electron emission, and a hollow member surrounding said emitting surface, an opening in
15 said hollow member for allowing a discharge to pass from said emitting surface to said anode, said anode being disposed outside of said hollow

member, said anode having a surface substantially blocking said opening.

12. A space discharge device comprising a gas-tight envelope containing an ionizable atmosphere, an anode and a cathode which during operation is maintained at an elevated temperature to give copious electron emission, said cathode comprising an electron-emitting surface adapted to be heated to a temperature of copious electron emission, and a hollow conducting member electrically connected to and surrounding
10 said emitting surface, an opening in said hollow member for allowing a discharge to pass from said emitting surface to said anode, said anode having a surface substantially blocking said opening.
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CHARLES G. SMITH.

CERTIFICATE OF CORRECTION.

Patent No. 2,137,198.

November 15, 1938.

CHARLES G. SMITH.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 10, for "well P" read wall P; page 3, first column, line 53, claim 5, after the word "cathode" insert structure; and line 71, claim 6, after "the" insert gas; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 27th day of December, A. D. 1938.

(Seal)

Henry Van Arsedale
Acting Commissioner of Patents.