Feb. 16, 1937. P. L. SPENCER 2,070,691

ELECTRON DISCHARGE DEVICE

Original Filed July 2, 1928

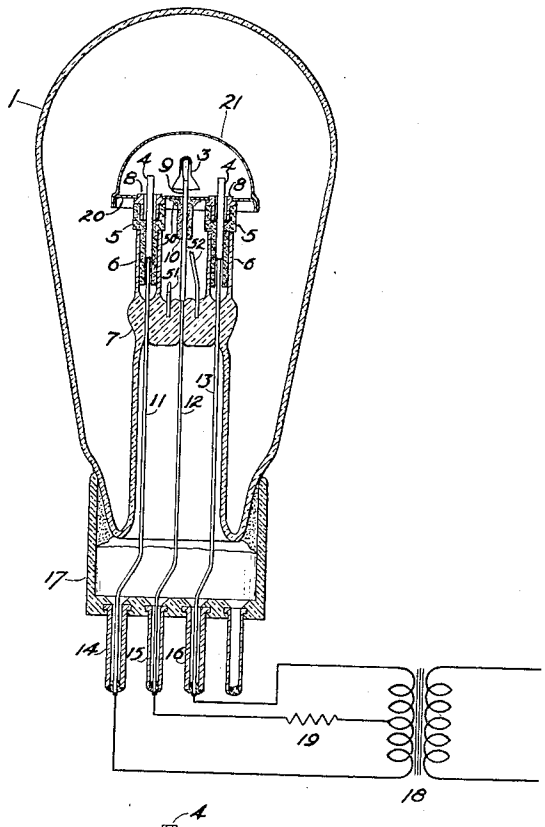


FIG. 1

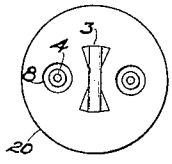


FIG. 2

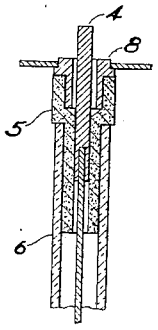


FIG. 3

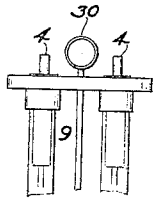


FIG. 4

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ELECTRON DISCHARGE DEVICE

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Application July 2, 1928, Serial No. 289,845
Renewed March 5, 1934

8 Claims. (Cl. 250—27.5)

My invention relates to an electron discharge device and has particular application to rectifiers of the gaseous type. Rectifiers in which spaced electrodes operate in a rarefied atmosphere are old and have been used for the rectification of currents of low value at moderate voltages. Such rectifiers whether thermionic or cold cathode type, are characterized by a simplicity of mechanism as well as operation, which make them very desirable for energizing vacuum tubes from lighting current. However, such rectifiers have hitherto been under the great disability of not being able to carry much current compared to the demands which a multi-tube modern radio receiving set requires. It is very undesirable because of expense to greatly increase the size of such rectifiers so that a greater output may be had. For the same reason, the duplication of two or more tubes is undesirable, especially since such tubes because of their characteristics are coupled in tandem only with the aid of auxiliary devices. The result is that rectifier tubes of this type as generally used in battery eliminators for radio sets, have a maximum output of about ⅛ amp. In order to render a multi-tube set completely a. c. operated, it is highly desirable that the available rectified output be of greater value.

One object of my invention, therefore, is to devise a rectifier of the gaseous conduction type which is substantially of the same physical size as ordinary rectifiers, but which at the same time, will have a much greater current carrying capacity. Another object is to devise such a rectifier which will be simple, easily manufactured, and of substantially the same cost as prior rectifying tubes of this type. Further objects are to devise a rectifying tube which will give a high current output at a high efficiency coupled with a long life and which will have no elements liable to be burned out.

My invention also relates to cathodes for electron discharge apparatus and applies equally well to the thermionic and non-thermionic type. An object of my invention, therefore, is to devise a cathode which has a low work function and can, therefore, emit electrons copiously. A further object is to obtain such emission from a thermionic cathode without heating the cathode to an excessively high temperature. Another object is to obtain such emission from a thermionic cathode without introducing excessive losses at the cathode surface. Another object of my invention is the production of electron-emitting material consisting of metallic material impregnated with alkaline-earths so that they cohere firmly in the desired form, and adhere more firmly thereby increasing the life of the material.

In general the tube embodying my invention comprises an exhausted envelope having a rarefied atmosphere of one or more of the rare gases and which may have in addition one or more alkali or alkaline earth metallic vapors to reduce the potential drop. Within this envelope and operating in such an atmosphere are cooperating electrodes comprising a cathode and at least one and preferably two anodes symmetrically disposed with respect to said cathode. The cathode which may be of any refractory material has its surface so treated that it possesses a low work function. Conversely the active surfaces of the anode may, if desired, be so treated that they have a correspondingly high work function, which has a tendency of inhibiting reverse discharge.

In the case of non-thermionic cathode, it is so fabricated that it has very large surface area compared to its mass and is preferably formed of a metallic wafer. In order to render this type of cathode more efficient, both in starting and operation, it is preferably, though not necessarily, so shaped that there is a considerable concave active surface.

The non-thermionic type is preferably provided with concave active surfaces. The discharge from a cathode generally tends to concentrate along such surfaces, probably because positively charged ions appear to have a tendency to congregate in a space which is partially or completely surrounded by active cathode surfaces. In thus congregating, they tend to attract more electrons from the cathode surface, thereby creating a very low drop in said surface. By shaping this type of cathode so that there is considerable active surface having a concave curvature, the tendency of the cathode discharge to concentrate in a pocket is promoted, thus rendering the starting of the tube easier and its operation certain and steady. The mass of the cathode is preferably small for reasons to be explained hereafter.

Although a discharge in the non-thermionic type of rectifier will be easily initiated and efficiently maintained with just the electrodes as mentioned, it is preferable, though not essential, to surround the region of discharge with an enclosure of metallic members. This enclosure tends to conserve the heat produced by the discharge, thus rendering it possible to maintain the discharge with greater efficiency. Furthermore, by completely enclosing the region of dis-

charge, the discharge is maintained between the desired active surfaces and is prevented from causing damage to the insulating or containing structure.

The shielding member is preferably insulated from the electrodes, and the insulation is preferably, though not necessarily, effected by the provision of short path insulating gaps.

In operation, the non-thermionic type of tube is characterized by the initiation of a glow discharge upon the application of a suitable potential. This glow discharge is visibly manifested by diffused glow encompassing the entire cathode. Almost immediately a small ball of fire appears to settle on the surface of the cathode, moving very swiftly therealong and is finally located in a pocket of said cathode. At the same time a brilliant glow surrounding the cathode shrinks in size but gains in brilliancy and becomes merged with the ball of fire. Each of the anodes has a bright region partially or completely surrounding it. This region is not as intense as the ball of fire and is not as large. This optical change in the character of the discharge is the physical manifestation of a change from the character of a glow discharge to that of an arc-like discharge. This change in the character of the discharge is accompanied by a drop in potential across the tube and an increase in the current through it.

Though I am not certain, it is my theory that this discharge is extinguished every cycle during the reverse period but is re-established by means of a hot spot on said cathode. This hot spot is sufficient to initiate the arc by means of thermionic emission. By making the cathode of small mass, the hot spot is effectively maintained during reverse periods. However, it is very unlikely that the operation of the cathode may be characterized as thermionic, even in a substantial degree, since the amount of current in the arc is far greater than thermionic emission from the active area of the cathode would warrant. A tube of this character and of a size substantially the same as the ordinary gaseous type of rectifier, can very easily rectify a current of ⅓ amp. and has actually passed more than ½ amp. throughout steadily and without any serious injury apparent. The voltage at which such current may be rectified may be substantially as high as the prior art rectifiers of this general type or may even be somewhat greater. Voltages as high as 600 across the anodes at the currents mentioned above, have been successfully rectified. In one case, a bridge of four of such rectifiers gave a combined output of 1100 volts at ½ amp. The cathode in such tubes is composed of a piece of tantalum ½ inch square and .003 inch thick.

In case of the thermionic type of rectifier, the cathode emitted electrons copiously at a reddish white heat.

Referring to the drawing, which is substantially full size,

Figure 1 shows a sectional view of a rectifier embodying a preferred form of my invention;

Figure 2 is a plan view of the cathode and anodes;

Figure 3 is a detailed sectional view of the anode insulating structure;

Figure 4 shows a modified form of cathode.

Referring to the drawing, 1 is the ordinary glass or other insulating envelope within which is a press 7. Supported on press 7 are two anodes 4 having lead-in wires 11 and 13 sealed in said press. A cathode 3 is suitably supported on a wire-like member 9. This member is sealed in the press to a lead-in wire 12. Wires 11, 12, and 13 from the anodes and cathode are joined to pins 14, 15, and 16 of base 17 which is suitably cemented to the bottom of envelope of 1. The tube is adapted to be plugged into a socket so that pins 14, 15, and 16 are connected to the secondary of a transformer 18. The two anodes are connected to the extreme ends of the secondary while the cathode is connected through a load 19 to the center of said secondary.

The anodes are surrounded by insulators 5 of lava or any suitable material fitting into projections 6 of press 7. As may be seen, these insulators have suitable shoulders so that the insulators will be supported by the projection 6. Each of said insulators has a center channel through which the anode and the lead wire pass. At the outer portion of said insulator 5 are fitted metallic bushings 8 of steel, aluminum, nickel, or any other suitable material. The bushings and insulator ends have conjugate interfitting surfaces so that the bushings may be fitted down and rest upon the insulators. Each of said bushings 8 has its center portion cut out to form a channel coaxial with said anodes and somewhat larger so as to leave an annular region. This region, though of considerable depth compared to the space between the anode surface and the inner bushing surface, is of such dimension that the distance between opposing surfaces is preferably of the order of the mean free path of the gas particles in said rectifier. In this way, bombardment by ions and electrons of the insulation is effectively eliminated. It is, of course, possible to dispense with bushings 8 entirely and suitably shape insulators 5 so that there is a region similar to that shown. Cathode supporting member 9 passes through an insulator 10 composed of lava or similar material retained in place against a plate 20 by means of an annular metallic member 50 which clamps the insulator in place. This member 50 is put over insulator 10 and thereafter welded to plate 20. It will be noted that the insulator and plate are cut away in the region of wire 9 to form a gap somewhat similar in form and function to the gaps around anodes 4.

Plate 20 previously mentioned above, is suitably apertured as shown in Figure 2 so that bushings 8 fit in. The upper free ends of bushings 8 are suitably shouldered so that plate 20 may be fitted thereon and supported thereby. The entire assembly of insulators and bushings with plate 20 is such that the electrodes are firmly retained in their relative position. Although plate 20 may have any configuration desired, it is preferable to have it circular. Covering the electrodes and active region of discharge from the top and sides is a dome-like member 21 which is welded to 20 at their meeting edges. Sealed in press 7 are two supporting wires 51 and 52, which, although not shown in the drawing, are welded to opposite points of the meeting edges of 20 and 21 to support the entire structure.

Cathode 3 which is welded to or suitably supported by member 9, is composed of a thin rectangularly shaped wafer of small mass. This wafer may be flat or substantially flat as disclosed in my prior application, Serial No. 183,405, filed April 13, 1927, of which this is a continuation in part. But preferably this wafer is curved over on itself to form a U-shaped member. Each of the four corners is thereafter flared out as more

clearly shown in Figures 1 and 2. While the cathode may be of any refractory material suitable for use, such as tantalum, molybdenum, platinum, or tungsten, I prefer tantalum. In order to impart to the surface of the tantalum or other cathode material a low work function, I coat the surface with certain substances. In the case of tantalum, I preferably oxidize the surface first in any suitable manner as by heating in gas flame. Thereafter I spray the cathode with a mixture of solutions of nitrates of barium, strontium, potassium, and if desired, other alkaline earth or alkali metals. These dissolved nitrates are burned into the metal by an intense flame. The process is thereafter repeated as often as may be desired. In the case of tantalum, the surface of the metal appears to become white, encrusted, and rough, while the metal itself becomes brittle. The latter indicates that the inner layers of metals have been reached and transformed by the alkaline earth and alkali metals. This operation is performed several times. While I am not certain as to exactly what happens, it is my belief that the nitrates become transformed by obscure chemical reactions into oxides. These oxides coating the outer surface of the metal impart thereto a low work function of desirable character.

In the case of a thermionic cathode, especially of the filamentary type, the same procedure is followed except that the metal is in wire form.

The anodes may be of any suitable material such as iron, nickel, aluminum, tungsten, or tantalum. To impart a high work function to the surface of the anodes, it is desirable to transform the metallic surfaces into oxides. This may be done by heating in a flame or heating to white heat during the welding of the anode and its lead-in wires. By thus treating the anodes, the tendency of reverse discharge to the cathode or arcing between anodes is effectively eliminated. In a thermionic tube, the anodes would be made into suitable plate form.

The tube is exhausted as customary with such devices and the component parts thereof freed of occluded gases, by heating to a high temperature, in accordance with well known practice. Thereafter, a gas or a mixture of gases is admitted until a pressure of between 15 and 25 mm. Hg is obtained. The gas or gases are preferably, though not necessarily, of the inert group and may comprise helium alone or a mixture of helium and argon or neon or any two of the above. If desired, a vapor of an alkali or alkaline earth metal such as caesium or potassium, may be admitted to reduce the potential drop between electrodes.

In Figure 4, I have shown a modified form of non-thermionic cathode in which a cylinder is used. This cylinder, although shown with its axis perpendicular to the line joining the two anodes, may be disposed in any manner whatsoever, both as regards its horizontal inclination to the line joining the anodes and the vertical inclination to the plane of plate 20. If desired, this cylinder may be vertical or may very well be in such position as to enclose the line joining the two anodes.

I claim:

1. A rectifier comprising a plurality of anodes and a cathode in a rarefied atmosphere, means comprising a metallic member completely enclosing the region of discharge, said metallic member being electrically insulated from said electrodes by mean free path spacing, said cathode being made of tantalum with alkaline earth metal compounds burned in so that the discharge starts as a glow and continues thereafter as an arc-like discharge.

2. A non-thermionic cathode of tantalum in the form of a doubled over wafer having alkaline-earth metal compounds burned into its surface.

3. A gaseous discharge rectifier of the type wherein the discharge is initiated in the form of a glow, comprising a gas tight envelope containing a relatively large-area cathode, a relatively small-area anode, and a gas filling at a pressure sufficiently low to prevent flow of substantial glow current from said anode to said cathode under application to said anode of a negative potential higher than the breakdown voltage of the gas, said cathode comprising a cavity portion with closely disposed walls spaced from each other a distance sufficiently short to concentrate in its interior glow discharges emanating from adjoining surfaces into intensified discharges, and extension surfaces diverging from said cavity portion and having sufficient area and angularity to cause glow discharges emanating on said adjoining extension surfaces to converge into said cavity portion and produce an arc-like discharge between the cavity portion and said anode at a fraction of the cathode fall voltage of the gas, the interior sides of said cathode cavity portion being made of tantalum with low-work-function metal compounds burned into the tantalum surface.

4. A gaseous discharge rectifier of the type wherein the discharge is initiated in the form of a glow, comprising a gas tight envelope containing a relatively large-area cathode formed of a conducting member having a cavity portion with closely folded walls and a portion with extensions flaring outwardly from the closely folded walls, a relatively small-area anode, and a gas filling at a pressure sufficiently low to prevent flow of substantial glow current from said anode to said cathode under application to said anode of a negative potential higher than the breakdown voltage of the gas, the width of the cathode cavity being sufficiently small and the area of the adjoining cathode extensions being sufficiently large to cause glow currents developed over the area of said cathode to converge into an arc-like discharge emanating from the space between the closely spaced cavity walls and operating at a fraction of the cathode fall voltage, the interior sides of said cathode cavity portion being made of tantalum with alkaline-earth metal compounds burned into the tantalum surface.

5. The method of making an electron-emitting cathode which comprises oxidizing a metal surface, coating said metal surface with an alkaline earth metal compound, burning said compound into said surface, mounting said cathode within a vessel, and exhausting said vessel while heating said cathode to a high temperature.

6. The method of making an electron-emitting cathode which comprises coating a metal surface with a material having a low work function, burning said material into said surface by an intense flame, mounting said cathode within a vessel, and exhausting said vessel while heating said cathode to a high temperature.

7. A gaseous discharge rectifier comprising a gas-tight envelope containing a relatively large-area cathode formed of a conducting member having a cavity portion with closely folded walls and a portion with an extension flaring outwardly

from the closely folded walls, an anode and a gas filling, the width of the cathode cavity being sufficiently small and the area of the adjoining cathode extension being sufficiently large to cause glow currents developed over the area of said cathode to converge into an arc-like discharge emanating from the space between the closely spaced cavity walls and operating at a fraction of the cathode fall voltage, the interior of the sides of said cavity portion being made of a metal having a low work function coating tenaciously retained on its surface.

8. A rectifier comprising an anode and a cathode in a rarefied atmosphere, means comprising a metallic member enclosing the region of discharge, said metallic member being electrically insulated from said electrodes, said cathode being made of tantalum with alkaline earth metal compounds burned in.

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