July 29, 1958 R. H. GEIGER 2,845,567

INDIRECTLY HEATED THERMIONIC CATHODE

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Fig. 1

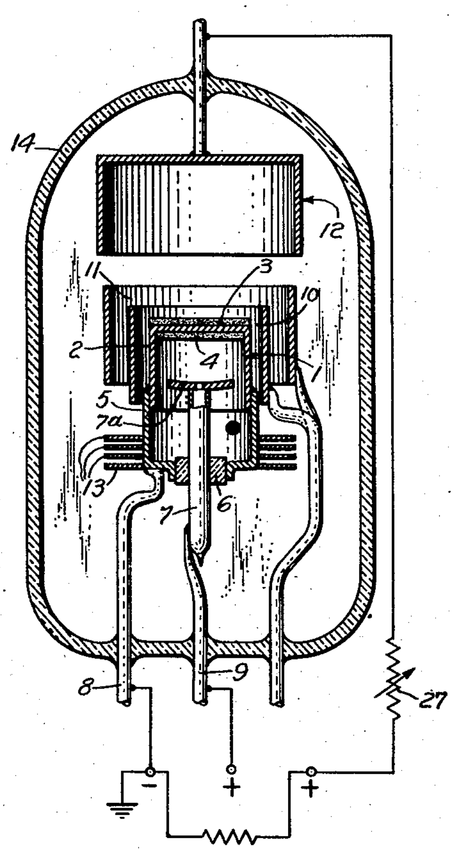
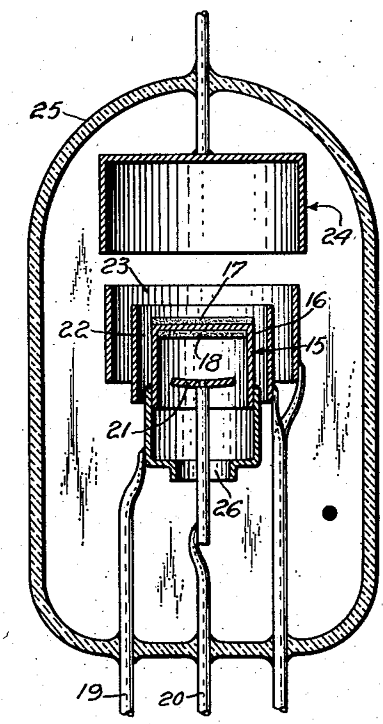


Fig. 2



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INDIRECTLY HEATED THERMIONIC CATHODE

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This invention relates to a cathode for use in electron discharge devices. It is more particularly directed to an indirectly heated thermionic cathode employing a cold cathode gas discharge.

In vacuum tube and gas tube electronic devices, cathodes which are employed are commonly of two types: directly heated cathodes and indirectly heated cathodes. For the first type, which is essentially a resistance-heated cathode, tungsten or thoriated tungsten is commonly employed as the metallic element. In order to insure an adequate emission of electrons, these metals must be brought to extremely high temperatures, and hence are directly heated. This offers the disadvantage that where tubes using these directly heated cathodes are employed as components of sensitive amplifiers, undesirable hum and other unwanted noise may be introduced into the amplifier because of the direct coupling of the heating element in the circuit. Consequently, to avoid these undesired effects, the use of indirectly heated oxide-coated cathodes has become common. These cathodes are indirectly heated usually by the radiation of heat from a filament maintained at a high temperature. Another method of heating these oxide-coated cathodes that has been utilized is the use of bombardment-heated cathode arrangements. In these latter devices, a filament of an electron-emitting metal is heated to a high temperature, and this filament serves as an emitter of electrons which bombard the internal or under surface of a coated cathode. The ensuing heating effect caused by the electron bombardment serves to make the cathode function as an indirectly heated one, with electrons being emitted from the external surface.

While the foregoing described cathodes are suitable for certain purposes, they have associated with them certain inherent disadvantages. Thus, the filaments employed with indirectly heated cathodes of the conventional type are subject to burn out. Special refractory coatings are required for these filaments. Where high current-carrying capacity is required, these filaments must be constructed of a large size and operate at very high temperatures. Furthermore, they have a low efficiency in that a relatively long length of cathode must be heated to obtain the desired emissivity from a narrower portion. Often the refractory coating of the heater flakes off, resulting in a short-circuit of the heater elements. If the cathode is of a complicated structure, the heat cannot be efficiently directed to the region where required.

It is therefore an object of the present invention to provide an indirectly heated cathode of considerably improved life compared with existing indirectly heated cathodes.

It is a further object to provide an indirectly heated cathode suitable for use in a gas discharge tube.

It is still a further object to provide a cathode structure capable of being focused for the more efficient heating of specific areas of the cathode.

It is a feature of this invention that a cathode is thermionically heated by being subjected to a positive-ion bombardment resulting from a cold cathode gas discharge.

Other objects and features of this invention may be seen from the accompanying figures wherein:

Fig. 1 is a sectional view of an embodiment of a vacuum tube employing this novel type cathode, and

Fig. 2 is a sectional view of another embodiment of a gas tube employing a similar type cathode.

Upon reference to Fig. 1, it is seen that the novel cathode structure **1** is composed of an upper cathodic portion **2**, preferably made of nickel, whose upper or exterior surface **3** is coated with an oxide coating. This may be any of the coatings normally employed such as one resulting from the chemical reduction of a deposit of the mixed carbonates of barium, strontium and calcium to the corresponding oxides. The lower or internal face **4** of the cathode is coated with a secondary emission type coating. Any of various materials may be used for this purpose. Thus, I have found that sputtered or evaporated metallic coatings of magnesium, barium, aluminum or cesium may be used. Also suitable for this purpose is an oxide coating such as one of aluminum oxide, magnesium oxide or barium oxide. Another satisfactory coating is a mixture of cesium oxide and silver. This upper cathodic portion is usually copper-brazed to a glass-sealing alloy forming the lower portion **5** of the cathode. A suitable alloy is one of nickel-iron-cobalt containing a small percentage of manganese, commercially available as Kovar. The entire cathode is enclosed by means of a ceramic plug **6** at its lower end through which an anode structure **7** is extended. This structure may be of a desired shape as indicated at *7a* so as to aim, focus or direct a positive-ion beam on a specific portion of the secondary emission surface. For ease in evacuating the cathode enclosure and then adding a given ionizable medium, it is preferable to use a hollow type anode whose end may be conveniently pinched off. This anode structure **7** is usually composed of the same metal, for example, Kovar, as the lower portion **5** of the cathode in order to simplify the forming of the metal-to-ceramic seal. Contained within this enclosed cathode structure is a non-electronegative gas or vapor. This gas is maintained at a pressure suitable for a maximum production of positive ions consistent with effective and efficient heating of the lower internal face of the cathode upon the establishment of a cold cathode gas discharge within the cathode enclosure. While a range of pressures may be used, the pressure required for optimum performance is a function of the desired tube voltages, the gas selected and the electrode geometry, and may be readily determined by simple techniques known to those skilled in this art. A suitable range of pressure is usually between approximately 1 and 10 millimeters of mercury. Suitable non-electronegative gases for this purpose are the rare gases, such as helium, neon, argon, krypton and xenon; and nitrogen, hydrogen and mercury vapor. The outer wall of the cathode is connected to an external terminal **8** which is usually grounded. The anode is connected to another external terminal **9**. Heat shields **10** and **11** may be provided to confine the electron emission of the cathode to the principal anode **12** and thereby make for more efficient emission on the part of the cathode. Cooling fins **13** are attached to the cathode structure in order to radiate heat away from the ceramic-to-metal seal which otherwise might be adversely affected. Upon sealing off the cathode enclosure filled with its ionizable medium, the remainder of the tube is highly evacuated and then sealed.

The vacuum tube is considered to operate as follows. Upon establishing a direct voltage or alternating voltage between electrode terminals **8** and **9**, the gas contained within the enclosed cathode structure is ionized and conduction occurs. The secondary emissive surface on the lower or internal face of the coated cathode wall serves to keep the cathode voltage drop relatively small. Inasmuch as the cathode is highly negative with respect to the anode 7, the positive ions of the contained gas are strongly attracted to the cathode face 4 and, because of their relatively high molecular weight, serve to bombard it vigorously. This results in a heating of the cathode face to a temperature sufficient for thermionic emission to occur from the upper emissive surface 3 of the cathode. The cathode 1 and the principal anode 12 are contained within the evacuated envelope 14 composed of hard glass or quartz or similar material and are cooperatively disposed to operate in relation to one another in a manner customary with similar type vacuum tubes. Inasmuch as the principal feature of this invention is directed to the provision of a novel type of indirectly heated cathode, it will be readily apparent to those skilled in the art that many modifications may be made within the discharge tube itself without departing from the spirit of this invention. Thus, it will be obvious to provide grid structures within the tube if triode, tetrode or pentode type tubes are desired.

Similarly, many other modifications may be made in the materials of construction of the tube without departing from the spirit of this invention. Thus, in place of the ceramic seal a Kovar-to-glass seal, using type 7052 glass, may be employed. In this instance, it would be preferable to have the radiating cooling fins located directly surrounding this coaxial type seal.

In Fig. 2, a gaseous discharge tube is illustrated, in contrast to the vacuum tube shown in Fig. 1, in which a related embodiment of the cathode structure is shown. Thus, in a manner similar to Fig. 1, there is shown in Fig. 2 a cathode structure 15 containing an upper cathode portion 16, composed preferably of nickel, whose upper or exterior surface 17 is coated with a mixed oxide coating of the oxides of barium, strontium and calcium, usually produced by chemical reduction of the corresponding mixed carbonates. The inner face 18 is similarly coated with one of the secondary emission materials as is used for coating face 4 as described for Fig. 1. However, the cathode is not fully enclosed in the embodiment shown in Fig. 2 because the gas contained within the cathode portion is of a similar type and at a similar pressure as the gas contained within the rest of the gas tube. Again, the non-electronegative type gases as described for Fig. 1 may be employed. This gas tube operates in a similar manner to that illustrated in Fig. 1 in that in connecting the external cathode terminal 19 and the external anode terminal 20 to a source of voltage, a discharge is set up between the cathode 15 and the anode 21. Positive-ion bombardment of the secondary emissive surface ensues, and thermionic emission occurs from the surface 17 upon this surface being brought to the required temperature. Similar heating shields 22 and 23 are provided to increase the cathode efficiency by directing the emitted electrons to the principal anode 24 enclosed within the envelope 25. Because the gas within the principal section of the tube and within the cathode enclosure is the same and at the identical pressure, the cathode enclosure need not be sealed off from the principal portion of the tube but rather includes a communicating passage 26 therebetween. This eliminates the need for metal-to-glass or ceramic seals at this point, with the associated cooling fins. The anode 21 may be of a solid rodlike construction since there is no need to separately evacuate and fill the cathode enclosure.

It will, of course, be realized that a certain amount of bombardment by positive ions of the exterior emissive surface 17 will occur, but this may be mitigated or otherwise controlled by changing the gas pressure or the principal anode voltage, such as by adjusting variable resistor 27, or by adding additional electrodes and the like, these being techniques well known to those skilled in the design of gas tubes. For certain purposes, it may be desirable to have a gas discharge tube in which the gas pressure in the principal portion of the tube is different from that within the cathode section. In such an event, the cathode may be made in the form of a completely enclosed structure similar to that shown in Fig. 1.

It will be seen from the foregoing figures that an indirectly heated cathode has been provided which does not depend upon the presence of a filament heated to a highly elevated temperature. Thereby the possibility of filament burn out has been eliminated. By using the cold cathode type of gas discharge as a source of positive ions, it is possible to focus the bombardment upon a relatively small sector of the cathode structure. Such an arrangement becomes of importance where intricate and involved cathode structures are required for certain specialized applications. Obviously a gas type discharge can follow a sinuous-shaped structure with considerable efficiency whereas a filamentary type heated structure cannot.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. An evacuated electron discharge vessel, an anode within the vessel, a cathode within the vessel containing emissive material cooperatively positioned adjacent said anode and means for maintaining said emissive material at a temperature of thermionic emission, said means including a cathode component which forms a wall part of a sealed-off discharge enclosure containing a non-electronegative gas, said wall part and said emissive material being in direct heat conducting relation, said enclosure formed by said cathode component further including within the said enclosure an anode for initiating and maintaining a cold-cathode positive-ion bombardment of said wall portion to maintain the emissive portion of said cathode at said temperature for thermionic emission and a lead to the anode disposed within the cathode housing and extending through an opening in a second wall portion of said cathode housing, a seal of insulating material is disposed between said anode and said second wall portion and heat-dissipating means are located adjacent to said seal to maintain it at a relatively low temperature.

2. An electron discharge vessel according to claim 1 wherein said cathode housing is substantially cylindrical in shape.

3. A cathode for an electron discharge device comprising a cathode housing having an outer wall portion thereof coated at least in part with an electron emissive material, an ionizable medium contained in said housing and an anode disposed within said housing to initiate and maintain a cold-cathode positive-ion bombardment of said wall portion to thereby effect thermionic emission of said coated portion, said wall portion and said coated portion being in heat conducting relation, and a lead to the anode disposed within the cathode housing and extending through an opening in a second wall portion of said cathode housing, a seal of insulating material is disposed between said anode and said second wall portion and heat-dissipating means are located adjacent to said seal to maintain it at a relatively low temperature.

4. A cathode for an electron discharge device comprising a cathode housing having an outer wall portion thereof coated at least in part with an electron emissive material, an ionizable medium contained in said housing and an anode disposed within said housing to initiate and maintain a cold-cathode positive-ion bombardment of said wall portion to thereby effect thermionic emission

of said coated portion, at least part of the inner surface of the coated wall portion of the cathode housing is coated with magnesium oxide and wherein at least part of the outer surface of said coated wall portion is initially coated with a mixture of the carbonates of barium, strontium and calcium.

5. An electron discharge device comprising an envelope having therewithin means defining a main discharge path including a main anode and a thermionic cathode having a surface cooperating with said main anode to provide said main discharge, means for heating said thermionic cathode comprising means for providing an auxiliary discharge path including an auxiliary anode, an auxiliary cathode surface and a non-electronegative gas in the path therebetween, said auxiliary cathode surface being positioned in heat conducting relation with said thermionic cathode surface and adapted to heat the same by said auxiliary discharge, and means to mitigate bombardment of said thermionic cathode by the positive ions of said non-electronegative gas.

6. An electron discharge device comprising an envelope having therewithin means defining a main discharge path including a main anode and a thermionic cathode having a surface cooperating with said main anode to provide said main discharge, means for heating said thermionic cathode comprising means for providing an auxiliary discharge path including an auxiliary anode, an auxiliary cathode surface and an ionizable medium in the path therebetween, said auxiliary cathode surface being positioned in heat conducting relation with said thermionic cathode surface and adapted to heat the same by said auxiliary discharge, and means to control the bombardment of said thermionic cathode by the positive ions of said ionizable medium.

7. An electron discharge device comprising an envelope having therewithin means defining a main discharge path including a main anode and a thermionic cathode having an electron emissive surface cooperating with said main anode to provide said main discharge, means for heating said electron emissive surface to the thermionic emissive temperature including a secondary emissive surface, a non-electronegative gas, and an auxiliary anode disposed adjacent said secondary emissive surface to initiate and maintain a cold-cathode positive-ion bombardment of said secondary emissive surface, said secondary emissive surface being positioned in heat conducting relation with said electron emissive surface and adapted to heat the same to said temperature by said positive-ion bombardment, and means to control the positive ion bombardment of said main cathode.

8. An electron discharge device comprising an envelope having therewithin a main anode, a cathode housing including on the exterior of a wall portion thereof adjacent said main anode a coating of thermionic electron emissive material to define together with said main anode a main discharge path, means for heating said electron emissive material to the thermionic emissive temperature including a coating of secondary emissive material on the interior of said wall portion in heat conducting relation with said electron emissive material, a non-electronegative gas, and an auxiliary anode disposed adjacent said secondary emissive material to initiate and maintain a cold-cathode positive-ion bombardment of said secondary emissive material to heat said electron emissive material to said temperature, and means to control the positive ion bombardment of said main cathode.

9. A vacuum electron discharge device comprising a vacuum envelope having therewithin a main anode, a gas tight cathode housing including on the exterior of a wall portion thereof adjacent said main anode a coating of thermionic electron emissive material to define together with said main anode a main discharge path and means for heating said electron emissive material to the thermionic emissive temperature including a coating of secondary emissive material on the interior of said wall portion in heat conducting relation with said electron emissive material, a non-electronegative gas contained in said cathode housing and an auxiliary anode disposed adjacent said secondary emissive material to initiate and maintain a cold-cathode positive-ion bombardment of said secondary emissive material to heat said electron emissive material to said temperature.

10. A device according to claim 9, wherein a lead to said auxiliary anode extends through an opening in a second wall portion of said cathode housing, a seal of insulating material is disposed between said anode and said second wall portion and heat-dissipating means disposed adjacent to said seal to maintain it at a relatively low temperature.

11. A gaseous electron discharge device comprising a vacuum envelope having therewithin a non-electronegative gas, a main anode, a cathode housing including on the exterior of a wall portion thereof adjacent said main anode a coating of thermionic electron emissive material to define together with said main anode a main discharge path, means for heating said electron emissive material to the thermionic emissive temperature including a coating of secondary emissive material on the interior of said wall portion in heat conducting relation with said electron emissive material, communicating means between said cathode housing and the principal space in said envelope in a second wall portion whereby said non-electronegative gas can communicate with the interior of said cathode housing and an auxiliary anode disposed adjacent said secondary emissive material to initiate and maintain a cold-cathode positive-ion bombardment of said secondary emissive material to heat said electron emissive material to said temperature, and means to reduce the positive ion bombardment of said main cathode.

12. A device according to claim 11, wherein a lead to said auxiliary anode extends through said communication means.

13. An indirectly heated thermionic cathode comprising a cathode housing having an outer wall portion thereof coated at least in part with an electron emissive material, an ionizable medium within said housing, a coating of secondary emissive material on the interior of said wall portion in heat conducting relation with said electron emissive material and an auxiliary anode disposed adjacent said secondary emissive material to initiate and maintain a cold-cathode positive-ion bombardment of said secondary emissive material to heat said electron emissive material to thermionic emissive temperatures.

14. A cathode according to claim 13, wherein said auxiliary anode is shaped and disposed in relation to said secondary emissive coating to effectively focus a stream of positive ions thereon.

15. An indirectly heated thermionic cathode comprising a gas tight cathode housing having an outer wall portion thereof coated at least in part with an electron emissive material, an ionizable medium disposed within said housing, a coating of secondary emissive material on the interior of said wall portion in heat conducting relation with said electron emissive material and an auxiliary anode disposed adjacent said secondary emissive material to initiate and maintain a cold-cathode positive-ion bombardment of said secondary emissive material to heat said electron emissive material to thermionic emissive temperatures.

16. A cathode according to claim 15, wherein a lead to said auxiliary anode extends through an opening in a second wall portion of said cathode housing, a seal of insulating material is disposed between said anode and said second wall portion and heat-dissipating means disposed adjacent to said seal to maintain it at a relatively low temperature.

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