

Aug. 17, 1954

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2,686,735

CATHODE MATERIAL

Filed Jan. 3, 1951

Fig. 1

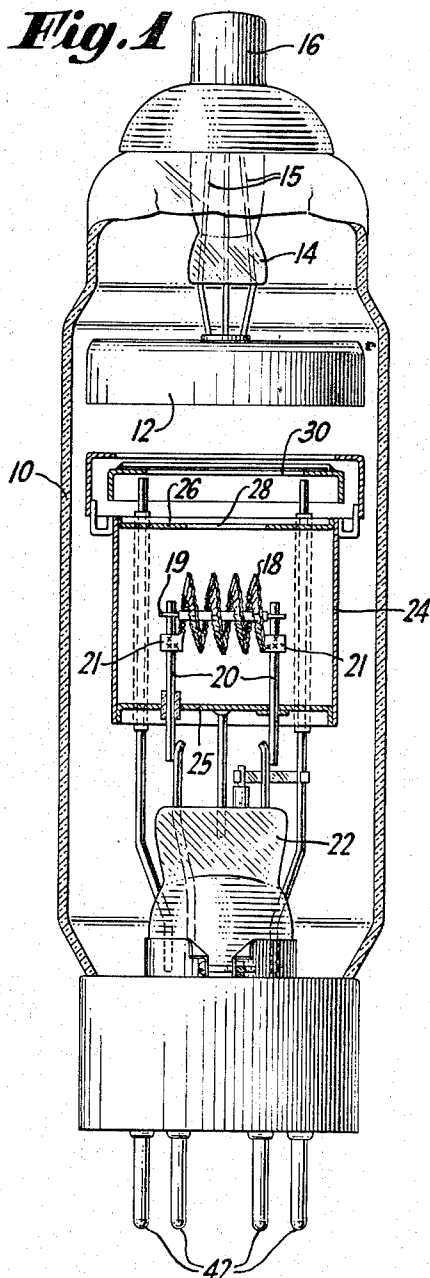


Fig. 2

CATHODE SPRAYED WITH
MIXTURE OF $BaCO_3$ AND Ni_2O_3
AND BINDER

COATED CATHODE FIRED IN H_2
ATMOSPHERE TO REDUCE Ni_2O_3
TO Ni AND TO SINTER Ni
PARTICLES TO CATHODE

FIRED CATHODE MOUNTED
IN TUBE

TUBE EXHAUSTED AND BAKED

CATHODE HEAT-TREATED
TO DECOMPOSE $BaCO_3$

METAL ELECTRODES DEGASSED
AND TUBE PUMPED OUT

INERT GAS ADMITTED TO
TUBE AND CATHODE EXPOSED
& POSITIVE ION BOMBARD-
MENT

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2,686,735

CATHODE MATERIAL

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Application January 3, 1951, Serial No. 204,149

4 Claims. (Cl. 117—33.26)

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My invention relates to a directly heated cathode structure, and more particularly to a filamentary type cathode for a gas discharge tube.

One type of thyatron gas tube employs a filamentary cathode electrode, an anode electrode and a control electrode or grid mounted between the anode and cathode electrodes. In operation, a difference of potential is established between the anode and cathode electrodes to produce an electron discharge therebetween. The tube is filled preferably with a monatomic gas to amplify the primary discharge between the cathode and anode electrodes. The average amount of current conducted by this type of tube can be varied within limits by the control grid electrode. A negative bias, more negative than a critical value, placed upon the control grid will prevent a gaseous discharge in the tube between cathode and anode. If the potential of the grid electrode is shifted so that it becomes more positive than a critical value, an electron sufficient to cause gas ionization. Under this condition the tube breaks down and there is current flow in the form of a gas discharge between the cathode and anode electrodes. At this point, the control electrode loses control of the tube and cannot stop the discharge even if the grid potential is shifted below the critical value. That is, a sufficiently negatively biased grid electrode can control the starting of the tube discharge but cannot control the tube discharge, once it has begun. In the usual application of this type of tube, a bias, below the critical value is normally maintained on the grid electrode. Means are provided to shift the grid bias above the critical value to permit tube conduction at any scheduled time.

In the type of gas control tube described above, the cathode conventionally comprises a filament coated with an electron emissive material which will emit a copious amount of electrons when heated by an appropriate current flowing there-through. One type of cathode coating material, which has been used to a large extent to act as a source of electrons, is a mixture of barium and strontium carbonates. However, I have found that a cathode coated with such a material does not have uniform emission over its whole surface due to the varying resistance of the coating from one portion to another of the cathode surface. Due to this fact, there occurs, during tube op-

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eration, a local heating within the coating which results in a sputtering or sparking of the cathode material when the current from the cathode is increased beyond certain limits. Due to such sparking, a bare area appears on the cathode and, if such a condition continues, the coating will be "sparked" from the cathode resulting in a short life for the tube. Such "sparking" or arcing, furthermore, causes a vaporization of the coating material, which will tend to condense on other elements of the tube such as the grid electrode, for example. The presence of cathode material on the grid will induce emission from the grid in a manner and the grid will lose control of the discharge, during tube operation.

It is thus an object of this invention to provide an improved cathode coating for a gaseous discharge tube.

It is another object of this invention to provide an improved cathode having a semi-conductive cathode coating to eliminate local heating of the cathode coating.

It is another object of this invention to provide an improved cathode structure having a coating which, during operation, will produce a minimum of vaporization of the coating material.

It is a further object of my invention to provide a cathode structure having an improved coating to provide a copious source of electrons and which will operate at a relatively low and an efficient temperature.

One form of my invention is the provision of a thermionic emissive coating for a cathode, which provides a relatively low resistance path through the coating, and also, which may be sintered to the cathode base to provide good conductivity between the cathode electrode and the emissive surface of the cathode coating. This invention proposes the use of a mixture of barium carbonate and nickel oxide which is first coated over the surface of a nickel cathode structure. The nickel cathode, with its coating, is fired in a hydrogen atmosphere to reduce the nickel oxide to a nickel metal and also to sinter a portion of the nickel formed to the metal surface of the cathode structure. After this firing, the coated cathode member is mounted within the tube and further activated to produce the desired emission characteristics.

The novel features which I believe to be char-

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acteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing, in which:

Figure 1 is a sectional view of a gas control tube incorporating a cathode made according to my invention.

Figure 2 is a chart showing the steps in the method used for forming the cathode according to my invention.

The gas control tube comprises an envelope 10 enclosing a plurality of electrodes. An anode electrode 12 in the shape of a circular plate structure is supported from the top of the tube envelope by a depending press structure 14. Appropriate leads 15 pass through the stem or press 14 and through the glass envelope 10 to an anode terminal contact 16. The cathode 18 is constructed as a corrugated ribbon bent in a circular spiral and is supported by the edges of the ribbon on a ceramic rod 19, which is supported by rods 20 mounted from the glass press 22 of the envelope, as shown in Fig. 1. The ends of the filamentary cathode 18 are fixed, such as by welding, at 21 to support rods 20, which are connected in turn, to respective metal base pins 42.

The cathode ribbon 18 is covered, with an electron emitting material. Surrounding the filamentary cathode 18 is a heat shield 24, which is principally a metal cylinder mounted coaxially with the circular anode 12. The heat shield 24 may be closed at the bottom by a circular metal plate 25 and at the upper end by a metal plate 26 having an aperture 23 at its center. Aperture 23 is preferably a circular opening coaxial with cylinder 24 and anode 12. The opening 23 provides a path for a discharge between the filamentary cathode 18 and the anode electrode 12. The purpose of the heat shield structure 24 is mainly to prevent the escape by radiation of heat from cathode 18 and to maintain the heat in the localized space around the cathode. This permits the use of a smaller filament current. Furthermore, shields 25 and 26 prevent large dissipation of heat to the other electrodes of the tube prevents these tube parts from operating at an excessive temperature during tube operation.

Mounted coaxially and in alignment with the heat shield aperture 23 and the cathode plate 12, and between the anode electrode 12 and the filamentary cathode 18, is a grid structure 30 for controlling the discharge between the anode and cathode electrodes.

An appropriate current passed through the filamentary cathode 18 heats it to a temperature at which there is a copious emission of electrons from the cathode surface. When a difference of potential is established between the anode 12 and the cathode 18 in a manner such that the anode 12 is positive and the cathode is negative, there will be an electron flow from the cathode 18 to the anode 12. In tubes of this type, it is desirable to amplify this electron discharge by providing a gaseous medium within the tube. After tube evacuation, a monatomic gas is admitted to the tube under a predetermined pressure. The pressure of the gas within the tube is critical and is usually of the order of 50 to 300 microns for the rare gases, as krypton, xenon, or argon. The electron discharge between the cathode 18 and anode 12 ionizes the gaseous medium to increase the amount of current flowing through the tube. This electrical discharge

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between the cathode 18 and anode 12 is confined to a path passing through aperture 23 and the control grid 30.

My invention is in the cathode 18 of the tube shown in Figure 1. One type of cathode coating commonly used in tubes of this type is a mixture of barium and strontium carbonates, which upon activation, are changed to barium oxides and strontium oxides. However, I have found that such a barium strontium oxide coating possesses a high resistance between the metal cathode support and the emissive surface of the cathode coating. Such a high resistive coating produces local hot spots in the coating, which initiate arcing or "sputtering" between the cathode and the anode electrodes. This arcing or "sputtering" has the disadvantage of evaporating the cathode material away from these portions of the cathode surface. This consequently shortens the life of the cathode electrode. Furthermore the cathode material, vaporized by the arc, tends to condense on the colder electrodes of the tube, such as grid 30 and anode 12 for example. Cathode material on these cold electrodes will cause primary emission from these electrodes when they become heated during operation. Primary emission from the grid structure 30, tends to change the control potential of the grid, so that it loses control of the tube.

A novel type of cathode coating, made according to my invention, eliminates the defects described above. Such a cathode coating is one consisting of a mixture of barium carbonate and nickel oxide. The cathode coating mixture is made of 60% by weight of barium carbonate (BaCO_3) and 40% by weight of nickel oxide (Ni_2O_3). This mixture is suspended in an ordinary nitrocellulose binder and then ball-milled for some 20 hours, to mix the components thoroughly and to reduce the particle size of the barium carbonate. The cathode ribbon 18 is preferably either nickel or a nickel alloy. Any other appropriate metal may be used, such as a nickel-cobalt alloy, tungsten, tantalum, etc. The barium carbonate-nickel oxide coating is sprayed onto the cathode ribbon 18 to a weight of between 5 to 8 milligrams per square centimeter. Upon drying, the sprayed coating is held to the surface of the nickel spiral 18 by the nitrocellulose binder. The sprayed cathode is next heated or fired in a hydrogen furnace at 1000° C. for 10 minutes. The atmosphere of the furnace may be either pure hydrogen or any gas having a reducing action such as forming gas, which is essentially 90% nitrogen and 10% hydrogen. The reducing atmosphere of the hydrogen furnace tends to reduce some of the nickel oxide of the coating to nickel. Also the firing of the cathode will sinter some of the nickel particles to the surface of the base metal of the cathode member 18. Optimum results are obtained when the temperature of the furnace is maintained at around 1000° C. A proportionately longer heating time at a lower temperature may be used. However, the use of a temperature, which is above 1100° C. will provide a cathode having a poor electron emission, unless the hydrogen or reducing gas is dry and then the reducing and sintering temperature may be as high as 1150° C.

The coated cathode, which has been fired in the hydrogen furnace, as described above, is mounted within the tube 10, in any manner, and preferably as described in Figure 1. The tube envelope 10 is then exhausted and the tube baked

at around 450° C. for approximately 10 minutes. This is standard procedure for removing water vapor from the tube. An electric current is next passed through cathode filament 18 to raise the temperature of the cathode to 1000° C. This tends to break-down the carbonates of the coating, not broken down by the previous firing. Also this heating step drives off the oxygen formed by the breaking down of the oxides present. In this process, the temperature of the cathode is gradually increased to 1075° C., over a period of 15 minutes, to complete the activation of the cathode. The gasses, which are given off, are removed by pumping during this period of time. The heating of the cathode is continued until there is a residual pressure of a micron or less of mercury in the tube. Also, during this period of time, the metal electrode portions of the tube such as the shield 24 and the grid portions 32 and 34, as well as the anode 12 are inductively heated to drive off the occluded gasses in these metal parts.

After the preceding steps, an inert gas, such as xenon for example, is introduced into the tube to a pressure between 50 to 200 microns of mercury. The cathode filament 18 is again heated to between 850° and 900° C., and a voltage is established between the cathode 18 and the anode 12 so that a gaseous discharge is set up in the tube and an anode current of approximately 3 amperes is drawn for about 3 seconds. This activates the cathode by reducing the oxides partially to their metals. The gas is next pumped out and again refilled with the inert gas and the above described discharge established again. This is repeated a second time to flush the oxygen from the tube, after which the tube is cooled and the getters 42 flashed. The tube is then filled to between 90 and 100 microns of xenon and sealed off for use. A base 40 is then fixed to the tube envelope in the well known manner to make suitable contacts 42 with the electrodes within the envelope. Figure 2 discloses the steps for processing such a tube.

During tube operation, when the cathode is heated to an operative temperature of between 800° C. and 850° C. an electron emission will take place. This electron emission will be increased by tube operation at normal filament voltages due to the additional activation of the cathode coating by positive ion bombardment.

The novel barium oxide nickel coating materially reduces the "sparking" or arcing that takes place on the surface of the cathode. This is apparently due to the presence of the nickel metal within the coating, which reduces the electrical resistance of the coating material and hence eliminates any local heating of the coating. Furthermore, it is believed that the rate of evaporation of the barium metal from the coating is considerably less than that from a conventional barium oxide strontium oxide coating. This is evidenced by the fact, that there is within the tube less evidence of primary grid emission which can be attributed to condensed cathode material on the grid electrode. It is further believed that the sintering of the nickel, formed in the coating to the metal cathode support, provides the distinct advantages observed. The sintering provides a direct contact between the coating and the metal cathode support, so that, as described above, the internal resistance of the cathode coating is materially reduced with the reduction in arcing.

The process of making my novel cathode coat-

ing described above, involves the use of 60% barium carbonate and 40% nickel oxide material in the original cathode coating mixture. This is an optimum ratio of the materials in the mixture. However, I have found that it is not necessary to be limited to these relative proportions of barium oxide and nickel oxide. The nickel oxide may be varied between 25% and 50% of the mixture.

Also, I have found that following the teachings of my invention, a successfully operated cathode can be made by coating the nickel coil support with a coating mixture comprising 40% nickel oxide and 60% of a barium strontium carbonate mixture instead of the barium carbonate and in which the same processing steps described above are used. Successfully operated cathodes have also been made with coatings composed of 10% nickel oxide and 90% of a mixture composed of approximately 4 parts barium carbonate, 5.5 parts strontium carbonate, and 5 parts of calcium carbonate. I have also found that the cathode coating of nickel oxide can be replaced with a mixture of barium carbonate and nickel powder. However, it has been found that the last two coatings described did not produce optimum emission.

It is believed that the favorable results produced by the novel cathode described above is due mainly to the dispersal within the coating of the nickel metal, as well as to the sintering of the nickel particles to the cathode support. A photomicrograph of a section of a nickel base cathode coated with 40% nickel oxide and 60% barium carbonate, processed as described above, indicates that the cathode coating consists of particles of nickel interspersed with the barium component and sintered to the surface of the nickel base cathode.

While certain specific embodiments have been illustrated and described, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What I claim is:

1. The method of preparing a cathode electrode for a discharge device, said method including the steps of, coating a metal base member with a mixture of barium carbonate and nickel oxide, the amount of nickel oxide being from 25% to 50% of the mixture, heating said coated base member in a hydrogen atmosphere to the sintering temperature of nickel to reduce the nickel oxide of the coating to nickel and to sinter part of the nickel formed to the metal base member.

2. The method of preparing the cathode electrode for a discharge device, said method including the steps of, coating a metal base member with a mixture of barium oxide and nickel oxide, the amount of nickel oxide being from 25% to 50% of the mixture, heating the coating in a reducing atmosphere to the sintering temperature of nickel to reduce the nickel oxide of the coating to nickel and to sinter to the metal base member some of the nickel formed.

3. The method of preparing a cathode electrode for a discharge device, said method including the steps of, coating a metal base member with a mixture of nickel oxide and at least one of the oxides of barium, strontium, and calcium, the amount of the nickel oxide being from 25% to 50% of the mixture, heating the coating in a reducing atmosphere to the sintering temperature of nickel to reduce the nickel

oxide of the coating to nickel and to sinter the nickel formed to the metal base member.

4. The method of preparing a cathode electrode for a discharge device, said method including the steps of, coating a metal base member with a mixture of nickel oxide and at least one of the oxides of barium, strontium and calcium, the amount of the nickel oxide being from 25% to 50% of the mixture, heating said coated base member to a temperature of approximately 1000° C. in a reducing atmosphere to reduce some of the nickel oxide of the coating to nickel and to sinter at least some of the nickel metal formed to the base member, and heating said coated metal base member to a temperature between

1000° C. and 1100° C. in vacuum to activate the cathode coating.

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