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1,935,939

PHOTO-ELECTRIC TUBE AND METHOD OF PRODUCING THE SAME

Filed July 24, 1926

FIG. 1.

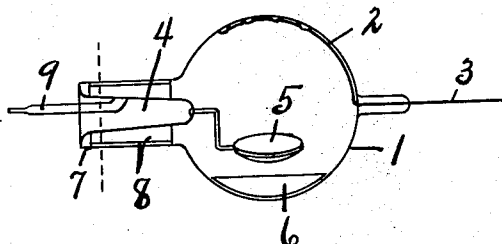


FIG. 2.

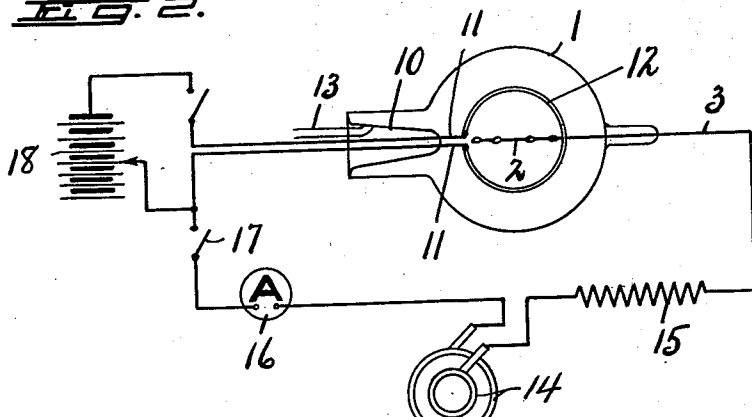


FIG. 3.

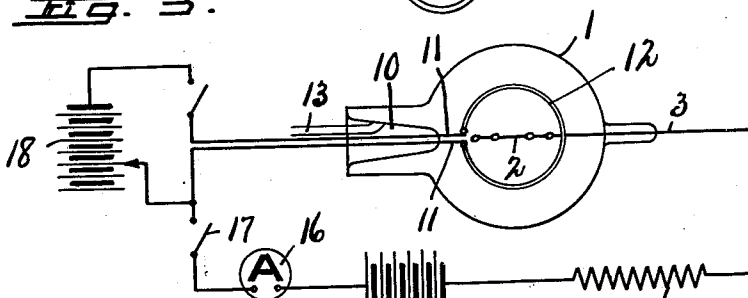
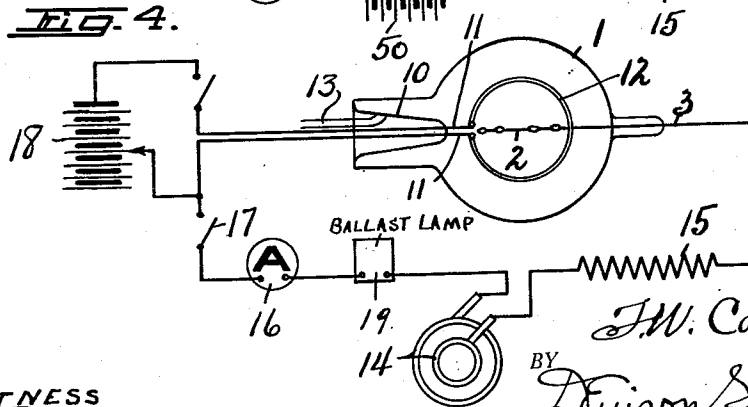


FIG. 4.



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PHOTO-ELECTRIC TUBE AND METHOD OF
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14 Claims. (Cl. 250—27.5)

This invention relates to a new and improved photo-electric tube and to the method of producing the same.

The main object of the invention is the production of a tube of greatly improved sensitivity accompanied by stability.

Other objects and advantages relate to the details of the tube and the method of producing the same, all as will more fully appear from the following description taken in connection with the accompanying drawing, in which:

The four figures diagrammatically illustrate various steps of the method and a suitable form and structure for the device.

The method of producing the tube may start with a suitable bulb 1, such as that illustrated in Figure 1. A platinum ribbon 2 is secured to the interior of the bulb in any suitable manner, as for instance by pressing comparatively small and closely associated portions of the glass inwardly as by a heated carbon rod to form projections in which the platinum ribbon is imbedded or partially imbedded. This platinum ribbon is connected to a lead 3 which may be of suitable material, such as tungsten and extends outwardly from the bulb.

A flare or stem 4 is then sealed into the tubular base of the bulb and carries a pan 5 of suitable material, such as sheet molybdenum. This pan contains a suitable amount of preferably silver, altho aluminum, copper or other metal which will stick to the glass may be used.

A portion of the interior wall of the bulb 1 is covered by a piece of mica or other suitable material 6 preferably in the form of a segment so as to cover a circular portion of the surface of the bulb. In addition, the tubular base 7 of the tube is preferably covered by a cylindrical piece of material 8, such as mica.

The stem 4 is further supplied with an exhaust tube 9 through which air can be drawn from the bulb.

A vacuum pump is then connected to the tube 9 and the bulb is exhausted to a very high vacuum, the usual precautions being taken to out-gas the glass of the bulb by baking. The structure in the form so far described is then placed in an induction coil furnace of any suitable and known type, and by passing high frequency current through the coil of the furnace the induced current in the molybdenum pan in the bulb causes the pan to become heated, and by varying the amount of current in the coil, the temperature in the pan can be brought to a point sufficiently high to volatilize the silver contained in the pan

over on to the interior wall of the glass bulb 1, and in contact with the platinum ribbon 2. The shield 6 prevents the portion of the glass which it covers from becoming coated with the volatilized silver and provides a transparent window 60 for the passage of light rays.

In addition the guard 8 prevents the depositing of the volatilized silver on the tubular base of the tube. The vacuum pump is then stopped and the tube 9 sealed off and the structure produced is allowed to cool for a considerable period of time, as for instance one-half hour. The tubular base of the bulb is then cut off at a suitable point, as for instance along the dotted line in Figure 1, and the stem and pan 5 removed from the bulb, leaving a bulb blank interiorly coated with silver, except for those portions protected by the shields 6 and 8.

There is then prepared a stem 10 with two leads 11 and upon these leads there is then mounted a ring 12 of platinum ribbon preferably in a plane substantially parallel with the window which was covered by the shield 6 during the silver depositing step. The platinum ribbon or ring is then heated in any suitable manner to a temperature of about 1000 degrees C. in air and the ring is then dipped into calcium nitrate to provide a coating for the ring.

The heat of the heated ribbon or ring decomposes the calcium nitrate and produces a thin evenly distributed film or coating of calcium oxide upon the ring. The ring or ribbon with its coating of calcium oxide is then dipped in barium nitrate, the heating being continued and the heat of the coated ribbon or ring decomposes the barium nitrate, giving an evenly distributed film of barium oxide super-imposed on the calcium oxide.

The stem with its appurtenances so produced is sealed into the blank produced, as heretofore described, to produce a structure of bulb, as diagrammatically illustrated in Figure 2.

The tube 13 is then connected to a vacuum pump and the bulb is again out-gassed by prolonged heating at a point just below where the glass will cave in, and the pump is continued in operation until there has been produced within the bulb the highest obtainable vacuum. During all of the pumping operation, the ribbon or ring 12 is maintained at a comparatively low temperature of say approximately 600 degrees C. with the ribbon in a dull red condition. When the highest vacuum obtainable has been produced, the temperature of the ring or ribbon 12 is raised to approximately 1400 degrees C. for a brief

period of for instance, 20 seconds, to insure that the gas is driven off the leads.

The temperature of the ribbon is then dropped to approximately 900 degrees C. and the ring 12 is connected in circuit with the lead 3, such circuit including a source of alternating current, as the generator 14 and preferably a resistance 15 and a measuring device such as the ammeter 16. An alternating current is then applied between the electrode 2 connected to the silver coating upon the interior of the bulb and to one of the leads from the platinum ring, the ribbon being maintained at a temperature of about 900 degrees C. The alternating current is applied to the circuit in an interrupted manner for a period of about one minute, as for instance by the use of a switch 17, applying the current to the circuit for one second and then breaking the circuit for a second, the operation being continued in the manner described for about one minute, whereby over-heating of the bulb is eliminated.

This operation of applying alternating current to the electrodes in the manner described has an effect upon the coating on the platinum loop 12 which makes it possible to later obtain an improved photo-active material from the ribbon. The bulb is then removed from the circuits described, and as illustrated in Figure 3, the electrodes 2 and 12 are connected in a circuit with a source of direct current as battery 50 with the silver coating to which it is connected made negative by about 400 volts, the circuit again including a suitable resistance 15 and a measuring device, as the ammeter 16.

The temperature of the ring or ribbon 12 is then raised to about 1400 degrees C. as for instance by suitable heating circuit including a source of potential, as battery 18. A hundred watt test lamp is placed close to the window in the bulb 1 to illuminate the tube, and by the use of the ammeter, it is possible to notice the current flowing in the circuit which slowly increases up to a maximum due to photo-electric action of the material, as barium metal or barium sub-oxide, thrown off the loop 12 and condensed on the silver coating upon the interior of the bulb 1.

In a bulb approximately two inches in diameter, the maximum value of the current obtained at this point is about fifteen to twenty micro-amperes. When the maximum is reached, the temperature of the loop 12 is immediately dropped to about 600 degrees C. The vacuum system is closed off, as by means of a cock in the line leading to the pump, and the circuit is again changed, as for instance, illustrated in Figure 4 so that a high voltage alternating current is applied to the two electrodes of the tube, i. e. to the loop 12 and the silver coating upon the interior of the bulb 1. This current is held down by a ballast lamp 19 so that only a small amount of current can pass through the bulb, as for instance approximately two milliamperes.

Hydrogen is then allowed to flow into the bulb through a suitable stop-cock and tube 13 until a condition is reached at which a glow discharge takes place within the bulb. The hydrogen should be preferably purified with great care. The produced glow is allowed to continue two or three minutes, preferably the current being applied intermittently and the temperature of the loop is then varied to give a condition where light blue streamers appear to shoot off in all directions from the loop 12. At this point the hydrogen within the bulb 1 is pumped out through the tube 13 and after a high vacuum has been produced

within the bulb, the electrodes are again connected in the original direct current circuit, as illustrated in Figure 3, and when the test lamp referred to is again applied close to the window, it is found that the sensitivity of the tube has increased to approximately 25 micro-amperes.

The temperature of the loop 12 is now brought to an experimentally determined value, probably about 700 or 800 degrees C. where the sensitivity starts again or continues to increase. The increase takes place rather slowly, reaching a maximum in about one hour and having a value of about 60 micro-amperes. The connection with the vacuum pump is then shut off and the heating circuit for the ring or electrode 12 is broken and the voltage in the test circuit illustrated in Figure 3 is reduced to about 180 volts.

Hydrogen is then run into the bulb, as for instance through tube 13 and the pressure is adjusted to give maximum sensitivity under a condition of low illumination of the tube, as for instance about 10 foot candles. After the pressure has been experimentally adjusted to maximum sensitivity, the bulb is removed from the circuit and the tube 13 is sealed off and the tube is completed.

The material thrown off from the platinum ribbon or filament 12 by the action of heat and condensed upon the metallic coating upon the interior of the bulb 1 when treated in the manner herein described gives to the tube many times the sensitivity of the known tubes and the resultant product is unusually constant and uniform in reaction, and altho I have described the exact process as utilizing barium, any other alkaline earth metal such as strontium or calcium may be used with perhaps less satisfactory results, and so far as I know, I am the first to construct a tube in which the bulb containing the electrodes also contains hydrogen, i. e. in which the electrodes of the tube remain constantly in an atmosphere of hydrogen, and altho I have shown and described a substantially exact process for producing a tube, I do not desire to restrict myself to the details of the process or all of the steps thereof, as various changes and modifications may be made in the process and to some extent in the tube itself without departing from the invention as set forth in the appended claims.

I claim:

1. The process of producing a photo-electric tube comprising coating a portion of the interior surface of the bulb with a metallic substance, inserting within the bulb a heatable electrode having a coating of a material adapted to be photo-active, heating the heatable electrode to throw off said coating in vaporized form and condensing the vaporized material upon the interior of said metallic coating on the bulb, connecting the metallic coating on the bulb in circuit with the heatable electrode, admitting hydrogen to the bulb until a condition is reached at which a glow discharge takes place between the electrodes, removing the hydrogen from the bulb, connecting the electrodes in circuit with a source of potential and maintaining said connection until the tube obtains a maximum sensitivity, then admitting hydrogen to the bulb until a pressure is reached which gives the desired sensitivity.

2. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, connect-

ing the metallic electrode in circuit with the heatable electrode and a source of alternating current, and causing the flow of current through said circuit for a comparatively brief period of time, then connecting the metallic electrode in circuit with the heatable element and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating, then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, withdrawing the hydrogen from the bulb and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, and maintaining said circuit until substantially the maximum sensitivity of the device is reached.

3. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, connecting the metallic electrode in circuit with the heatable electrode and a source of alternating current, and causing the flow of current through said circuit for a comparatively brief period of time, then connecting the metallic electrode in circuit with the heatable electrode and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating, then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, then adjusting the temperature of the heatable electrode until streamers appear to shoot off from said electrode, withdrawing the hydrogen from the bulb and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, and maintaining said circuit until substantially the maximum sensitivity of the device is reached.

4. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, connecting the metallic electrode in circuit with the heatable electrode and a source of alternating current, and causing the flow of current through said circuit for a comparatively brief period of time, then connecting the metallic electrode in circuit with the heatable electrode and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating, then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current, and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, withdrawing the hydrogen from the bulb and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, maintaining said circuit until substantially the maximum sensitivity of the device is reached, and then

admitting hydrogen to the bulb, and sealing off the bulb.

5. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, connecting the metallic electrode in circuit with the heatable electrode and a source of alternating current, and causing the flow of current through said circuit for a comparatively brief period of time, then connecting the metallic electrode in circuit with the heatable element and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating, then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current, and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, then adjusting the temperature of the heatable electrode until streamers appear to shoot off from said electrode, withdrawing the hydrogen from the bulb and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, maintaining said circuit until substantially the maximum sensitivity of the device is reached, and then admitting hydrogen to the bulb and sealing off the bulb.

6. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, then connecting the metallic electrode in circuit with the heatable electrode and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating, then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, withdrawing the hydrogen from the bulb, and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, and maintaining said circuit until substantially the maximum sensitivity of the device is reached.

7. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, then connecting the metallic electrode in circuit with the heatable element and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating, then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, then adjusting the temperature of the heatable electrode until streamers appear to shoot off from said electrode, withdrawing the hydrogen from the bulb and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, and maintaining said circuit until substan-

tially the maximum sensitivity of the device is reached.

8. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, then connecting the metallic electrode in circuit with the heatable element and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating; then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current, and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, withdrawing the hydrogen from the bulb and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, maintaining said circuit until substantially the maximum sensitivity of the device is reached, and then admitting hydrogen to the bulb, and sealing off the bulb.
9. The process of producing a photo-electric tube comprising coating a portion of the interior of a bulb with a metallic substance, inserting within the bulb a heatable electrode including a material adapted to be photo-active, then connecting the metallic electrode in circuit with the heatable electrode and a source of direct current, and heating the heatable electrode to throw off said material adapted to be photo-active in vaporized form, and condensing the same upon the metallic coating, then connecting the metallic coating in circuit with the heatable electrode and a source of alternating current and a means for holding down the amount of current flowing in the circuit, admitting hydrogen to the bulb until a glow discharge takes place, then adjusting the temperature of the heatable electrode until streamers appear to shoot off from said electrode, withdrawing the hydrogen from the bulb and connecting the metallic coating and the heatable electrode in circuit with a source of direct current, maintaining said circuit until substantially the maximum sensitivity of the device is reached, and then admitting hydrogen to the bulb and sealing off the bulb.
10. The process of producing a photo-electric tube comprising placing two spaced electrodes within the bulb, one of which includes an alkaline earth metal, evacuating the bulb, introducing hydrogen into the bulb and causing a glow discharge to take place within the bulb between the electrodes, withdrawing the hydrogen from the bulb, connecting the electrodes in circuit with a

source of potential while the bulb is free from hydrogen and maintaining such connection until the desired sensitivity is reached.

11. The process of producing a photo-electric tube comprising placing two spaced electrodes within a bulb, one of which is heatable and includes an alkaline earth metal, evacuating the bulb, heating the heatable electrode to a temperature sufficient to vaporize the alkaline earth metal, and depositing the same upon the other electrode, introducing hydrogen into the bulb, causing a glow discharge to take place within the bulb between the electrodes, withdrawing the hydrogen from the bulb, connecting the electrodes in circuit with a source of potential while the bulb is free from hydrogen and maintaining such connection until the desired sensitivity is reached.

12. The process of producing a photo-electric tube comprising placing two spaced electrodes within the bulb, one of which includes an alkaline earth metal, evacuating the bulb, introducing hydrogen into the bulb and causing a glow discharge to take place within the bulb between the electrodes, withdrawing the hydrogen from the bulb, connecting the electrodes in circuit with a source of potential and maintaining such connection until the desired sensitivity is reached, and admitting hydrogen to the bulb.

13. The process of producing a photo-electric tube comprising placing two spaced electrodes within a bulb, one of which is heatable and includes an alkaline earth metal, evacuating the bulb, heating the heatable electrode to a temperature sufficient to vaporize the alkaline earth metal, and depositing the same upon the other electrode, introducing hydrogen into the bulb, causing a glow discharge to take place within the bulb between the electrodes, withdrawing the hydrogen from the bulb, connecting the electrodes in circuit with a source of potential and maintaining such connection until the desired sensitivity is reached, and admitting hydrogen to the bulb.

14. The process of producing a photo-electric tube comprising placing two spaced electrodes within the bulb, one of which electrodes includes barium, evacuating the bulb, introducing hydrogen into the bulb and causing a glow discharge to take place within the bulb between the electrodes, withdrawing the hydrogen from the bulb, connecting the electrodes in circuit with a source of potential while the bulb is free from hydrogen, and maintaining such connection until the desired sensitivity is reached while a vacuum is maintained.

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