

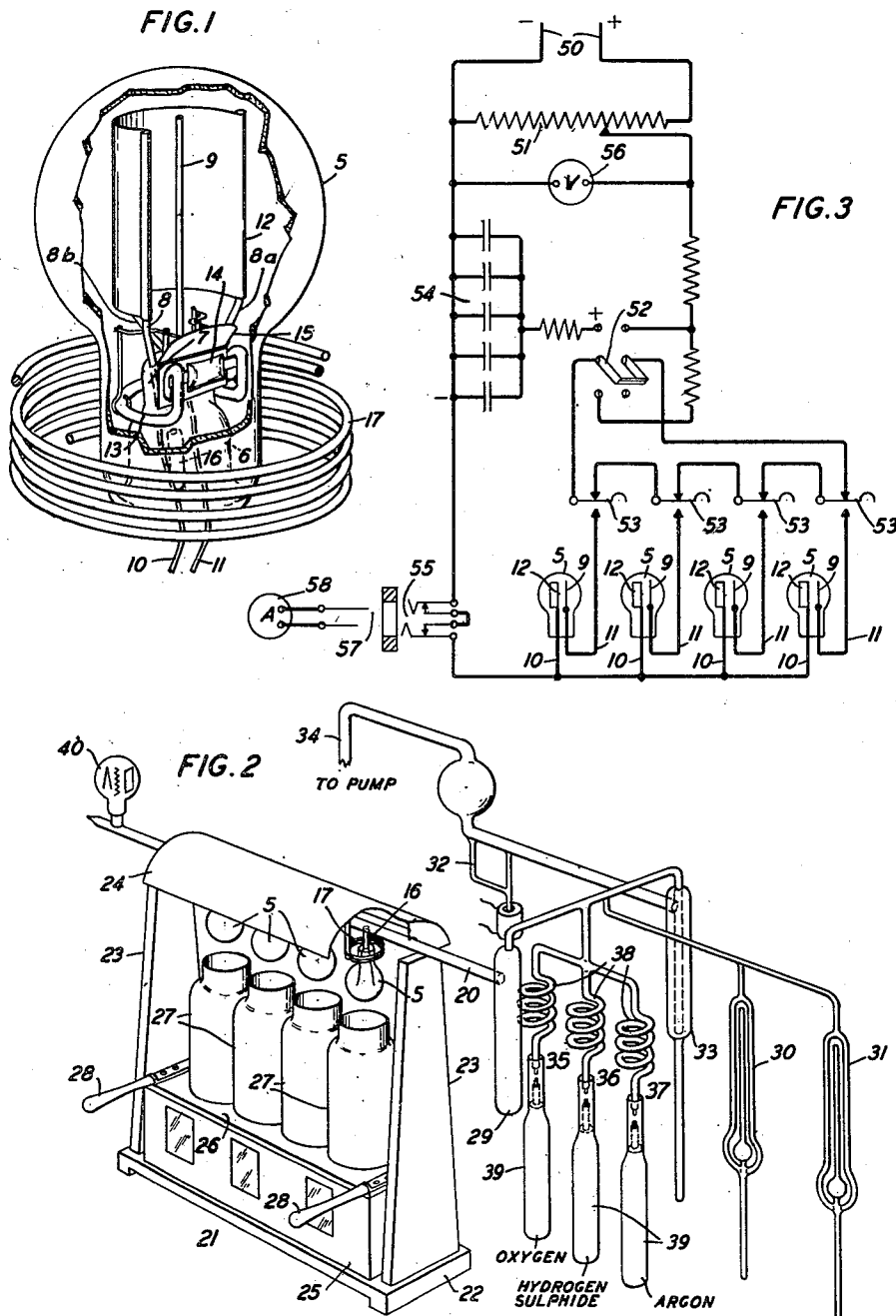
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PHOTOELECTRIC TUBE

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PHOTOELECTRIC TUBE

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This invention relates to photoelectric tubes and more particularly to cathodes therefor and methods of making such cathodes.

An object of the invention is to provide an improved composite electron emitting cathode.

Photoelectric tubes are now used for a great variety of purposes among which may be mentioned the matching of colors and television of colored objects. For these purposes it is sometimes advantageous to utilize a photoelectric tube having a spectral response characteristic approximating that of the human eye. As is well known, the average human eye is most responsive to greenish-yellow light, that is, to light of wave-lengths in the neighborhood of 5500 Å. U. (Ångstrom units).

A photoelectric cathode manufactured in accordance with this invention is stable under relatively high temperatures and in a glass envelope has a spectral response approximately like that of the human eye. A typical cathode according to this invention comprises a roughened silver plate carrying a thin layer of an intimate mixture of finely divided caesium, caesium sulphide and metallic silver on the exposed surface of which caesium is adsorbed.

A typical process for producing such a cathode comprises oxidizing by a glow discharge in oxygen, a substantially pure silver plate which is mounted in an evacuated glass bulb reducing the silver oxide by heat to leave a roughened silver surface, producing a thin layer of silver sulphide by a glow discharge in hydrogen sulphide, and finally exposing the silver sulphide to caesium vapor under suitable temperature conditions. An unexpectedly stable photoelectric cathode results from this process which cathode has a spectral sensitivity approximating that of the human eye.

The invention will now be described more in detail having reference to the accompanying drawing.

Fig. 1 shows the structure of a completed photoelectric tube according to this invention.

Fig. 2 illustrates a pumping station suitable for processing four tubes concurrently.

Fig. 3 is a schematic electric circuit used in processing such tubes.

The photoelectric tube illustrated in Fig. 1 comprises a glass bulb 5 having a reentrant stem 6 sealed therein. The stem 6 is provided with a press 7 in which are sealed cathode support wires 8, 8a and 8b, an anode wire 9, lead-in wires 10 and 11 connected to support wire 8 and anode wire 9, respectively. A cathode 12 comprises a semi-cylindrical silver plate, the straight edges

of which are rolled around the support wires 8 and 8a and to the lower rear edge of which support wire 8b is connected. Also supported by wires sealed into the press 7 is a heavy copper wire 13 which partially encircles the stem 6 and between the ends of which is a metallic capsule 14. This capsule 14 encloses a mixture for producing caesium vapor when heated. A nickel shield 15 is supported, also from wires sealed into the press 7, between the capsule 14 and the press 7 and the concave surface of cathode 12. The stem 6 is provided with an exhaust tube 16.

A coil 17 is arranged to induce current in the copper wire 13 and capsule 14 for heating the mixture within the capsule to its reaction temperature. This coil 17 is used only during the processing of the cathode 12 and is shown in partial section in Fig. 1. A portion of the glass bulb 5 is shown removed for clearness of illustration.

The electrode and accessory structure carried by the stem 6 is fabricated before the stem is sealed into the glass tube 5. The cathode plate 12 is formed from a polished silver sheet of a high degree of purity which has a clean mirror finish. The formed cathode is washed and reduced in hydrogen. The concave surface of the cathode has an area of about 2½ square inches. The anode 9 is a nickel wire.

The caesium producing mixture within the capsule 14 is in the form of a compressed pellet which is composed of approximately 5 milligrams of caesium chromate, Cs₂CrO₄, 32 milligrams of chromic oxide, Cr₂O₃, and 13 milligrams of powdered aluminum, Al. These ingredients are carefully prepared, finely pulverized and thoroughly mixed in proper proportions before being formed into pellets.

The pumping station illustrated in Fig. 2 is adapted for the processing of four tubes concurrently. The tubes 5 are sealed to a glass header 20 by exhaust tubes 16. This header 20 runs through an oven 21 which comprises a base 22 carrying end supports 23, on the upper ends of which is a metallic cap 24. An electric heater 25 between the supports 23 is surmounted by a removable cover 26 carrying four chimneys 27. This cover is provided with handles 28. The heater 25, cover 26 and chimneys 27 may be raised as a unit so that the chimneys surround the bulbs 5. Each chimney is provided with a slidable baffle (not shown) to control the convection air currents flowing therethrough. With the cover 26 and chimneys 27 removed, the heater

25 may be raised up against the cap 24 to completely surround the bulbs 5.

The header 20 is connected to a pumping apparatus comprising a liquid air trap 29, two McLeod gauges 30 and 31, a mercury vapor pump 32, a mercury cut-off 33, and a vacuum pump (not shown) connected to tube 34. Between the mercury cut-off 33 and the liquid air trap 29 three gas supply units 35, 36 and 37 are connected to the pumping apparatus. Each unit comprises a flexible coiled glass tube 38 associated with a gas container 39 through a mercury seal surrounding a pair of porous plugs of "Lavite" which when brought together permit gas to pass from the container 39 to the bulbs 5 through the glass coil 38. An ionization manometer 40 is connected to the other end of the header 20.

An electrical circuit used during the processing of four tubes while they are sealed on the pumping station is illustrated in Fig. 3. This circuit comprises conductors 50 adapted to be connected to a direct current source (not shown) and a potentiometer 51 for determining the potentials to be impressed across electrodes 9 and 12 of tubes 5. With the switch 52 in its lower position and jack 55 closed, a potential may be impressed on any one of tubes 5 by closing the lower contacts of switch 53 which is individual to such tube. With the switch 52 in its upper position, the potential determined by potentiometer 51 is impressed through the upper contacts of all of switches 53 in series on condensers 54 which have a total capacitance of 5 microfarads. Condensers 54 can then be discharged through any one of tubes 5 by closing the lower contacts of the corresponding switch 53. The voltage determined by potentiometer 51 is indicated by voltmeter 56. The current flowing through tubes 5 during a later stage of the processing is indicated by an ammeter 58 which may be connected into the circuit by inserting plug 57 into jack 55.

The processing of four tubes after the untreated assemblies have been sealed onto the header 20 will now be described.

The tubes 5 are sealed onto the header 20 with the concave sides of the cathode plates 12 facing directly forward, with the bulbs 5 centered with respect to the high frequency coils 17, and at such a height that the circular portion of the wire 13 is approximately midway of the coil 17 longitudinally.

The vacuum pump is turned on. The liquid air trap is cooled with a mixture of "Cellosolve acetate" and solidified carbon dioxide. When the pressure has fallen sufficiently, the manometer 40 is turned on. The heater 25, without the cover 26 and chimneys 27, is raised to engage the cap 24. The current is turned on to bring the oven temperature up to 400° C. and maintained until the manometer shows a pressure of 5×10^{-5} mm. of Hg (millimeters of mercury) or lower when the current is shut off and the oven allowed to cool. Slow leaks anywhere in the system are indicated if the pressure is not less than 2×10^{-5} mm. of Hg when the tubes are cooled to room temperature. If leaks are indicated they should be eliminated before the processing proceeds. This treatment removes occluded gases from the tubes but does not cause any chemical reaction in the caesium pellet. The pumping station is then flushed with oxygen from gas supply unit 35 until a clear green haze is obtained in the manometer 40 which indicates sufficient purity of the oxygen.

The mercury cut-off 33 is now closed to cut off the vacuum pumps and the manometer 40 turned off. Additional oxygen is admitted to a pressure of 2.2 mm. of Hg as indicated by McLeod gauge 30. Switch 52 of the electrical circuit of Fig. 3 is set in its lower position and the potentiometer 51 adjusted so that voltmeter 56 shows a voltage of 700 volts. Switches 53 are then operated in succession to close their lower contacts so that each cathode 12 in succession is subjected to positive ion bombardment. The first effect of such bombardment is to produce a heavy layer of silver oxide on the concave surface of the cathode 12, followed by a heating up of the silver plate and reduction of the layer of silver oxide. The cathodes are allowed to cool, the oxygen pressure again adjusted to 2.2 mm. of Hg and the oxidation, reduction and cooling repeated. The mercury cut-off 33 is then opened and the oxygen pumped out.

This treatment leaves the concave surface of each cathode 12 clean and slightly rough so that it has a uniform matte finish.

After a good vacuum has again been obtained, as indicated by the manometer 40, the mercury cut-off 33 is again closed and the manometer turned off. Hydrogen sulphide gas through gas supply unit 36 is admitted to a pressure of 2.0 mm. of Hg. Switch 52 is thrown to its upper position after potentiometer 51 has been adjusted so that voltmeter 56 shows a voltage of 650 volts. Each tube 5 is then subjected to a series of discharges from condensers 54 by the operation of closing switches 53 on their lower contacts. This operation is hereinafter called "tapping". The switch 52 in its upper position is therefore said to be in the "tapping position". Each switch 53 is tapped fifty times in four groups of twenty taps each and one group of ten taps. The first group of taps is applied to the four tubes in succession, then the second group, and so on until each tube has received the required number of taps or discharges. The mercury cut-off is again opened and the hydrogen sulphide gas pumped out. The manometer is again turned on and the pumping continued until the pressure is down to 3×10^{-5} mm. of Hg or less.

This treatment with hydrogen sulphide gas produces a thin layer of silver sulphide on the concave surface of each cathode 12. At each tap of a switch 53 a glow discharge occurs in the associated tube 5 and the cathode 12 of that tube is bombarded with a definite number of positive ions. The amount of silver sulphide which is formed is therefore closely controlled.

The cathodes 12 are now in condition to be treated with caesium vapor under suitable temperature conditions. A source of high frequency current (not shown) is connected to the coils 17 in succession to "flash" the caesium capsules, that is, to induce sufficient current in the copper wire 13 and capsule 14 to start a chemical reaction of the ingredients of the caesium pellet. The exothermic reaction which follows develops a large amount of heat and causes the immediate and complete expulsion of all of the caesium. The high frequency source is disconnected as soon as the reaction starts. The caesium travels in straight lines from the capsule 14 and is condensed on the glass walls of the bulb 5. The shield 15 prevents the hot caesium vapor from impinging on the cathode surface. This shield 15 is so shaped that it lies substantially parallel to the magnetic lines of force produced by the high frequency current in the coil 17 and therefore

is not heated to any great extent by eddy currents induced therein.

Immediately after the caesium capsule has been flashed stem heaters (not shown) are inserted around the stems of the tubes 5. Thermocouples are placed against each bulb 5 at the surface opposite the stem to indicate temperatures. The cover 26 with the chimneys 27 are placed on the heater 25 and the whole raised until a chimney 27 surrounds each bulb 5. The stem heaters are turned on first and after two minutes the heater 25 is turned on to quickly bring up the temperature of the convection air currents flowing past the bulbs 5. When the hottest bulb reaches a temperature of 150° C. the heater 25 is regulated to hold this temperature for five minutes. At the end of this five-minute period the heater 25 is again regulated to raise the temperature of the air currents to quickly bring the temperature of the hottest bulb 5 up to 225° C. The heater 25 is then regulated to hold this temperature until the cathode surface of each tube has reached the proper sensitivity.

The sensitivity may be indicated by the ammeter 58 when connected into the circuit of Fig. 3 by the insertion of plug 57 into jack 55. Each cathode 12 may be illuminated by a source of light (not shown). The potentiometer 51 is adjusted to give a voltage of 50 volts as shown on voltmeter 56. Switch 52 is closed in its lower position. The sensitivity of each tube 5 will be indicated by the ammeter 58 if the corresponding switch 53 is closed in its lower position. The tubes 5 are tested from time to time while illuminated and the hot air treatment is continued until the photoelectric current tends to decrease. As each tube reaches its proper sensitivity the air current for that tube is cut off. When all of the tubes have reached the proper sensitivity, the chimneys 27 are lowered and the bulbs allowed to cool to room temperature with the pumping apparatus still on.

When the bulbs 5 are cool and the pressure is down to 2×10^{-5} mm. of Hg, mercury cut-off 33 is closed and argon is admitted from the gas supply unit 37. The argon is admitted until the pressure assumes a steady state at the desired value, when the tube is sealed off from the header 20 by sealing off the exhaust tube 16. The pressure of argon is dependent upon the amount of gas amplification desired in the completed tube. A suitable pressure is 5×10^{-2} mm. of Hg.

Stable cathodes may be produced by varying considerably the specific process described in detail hereinbefore. However, in all such variations the silver surface is so treated with hydrogen sulphide gas as to produce a layer of silver sulphide on the cathode, which layer is subjected to heated caesium vapor to reduce at least some of the silver sulphide to form caesium sulphide and finely divided metallic silver.

The remaining free caesium is in a finely di-

vided state. In fact it may be so finely divided that the particles are approaching atomic dimensions, so that the behavior of an atom will depend more upon the other ingredients in the cathode layer than upon neighboring atoms of caesium. The cathode, therefore, may be said to comprise a mixture of finely divided caesium sulphide and metallic silver throughout which mixture is adsorbed free caesium. Some of the caesium also may well be alloyed or absorbed in the free silver particles or underlying rough silver surface.

The roughened silver surface may be produced in other ways than by oxidation and reduction of the silver oxide. The treated silver surface may also consist of a layer of silver on a plate of another metal, such as copper or nickel.

Stable cathodes may also be formed by subjecting the sulphided silver surface to the vapor of others of the alkali metals, rubidium, lithium, potassium and sodium.

The preferred form of the invention, however, is that described in detail hereinbefore since that process produces an electron emitting cathode which is stable at relatively high temperatures and has a spectral response closely approximating that of the human eye.

What is claimed is:

1. A method of producing a light-sensitive electron emitting cathode within a closed container, which comprises mounting an element having a polished silver surface within said container, producing a glow discharge on said surface in an atmosphere of oxygen to produce a heavy layer of silver oxide, heating said element to reduce said silver oxide, cooling said element, producing a glow discharge on the resulting surface of said element in an atmosphere of hydrogen sulphide gas at low pressure to produce a thin layer of silver sulphide, stopping the glow discharge, removing the residual gas from the container, producing caesium vapor within said container, and heating the container to cause the caesium to diffuse into the layer of silver sulphide.

2. A method of producing a light-sensitive electron emitting cathode within a closed container, which comprises mounting an element having a polished silver surface within said container, producing a glow discharge on said surface in an atmosphere of oxygen to produce a heavy layer of silver oxide, continuing the discharge until the layer of silver oxide is reduced leaving a clean rough silver surface, cooling said element, producing a glow discharge on the resulting surface of said element in an atmosphere of hydrogen sulphide gas at low pressure to produce a thin layer of silver sulphide, stopping the glow discharge, removing the residual gas from the container, producing caesium vapor within said container, and heating the container to cause the caesium to diffuse into the layer of silver sulphide.

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