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R. B. JANES

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PHOTOELECTRIC ELECTRON MULTIPLIER

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Fig. 1.

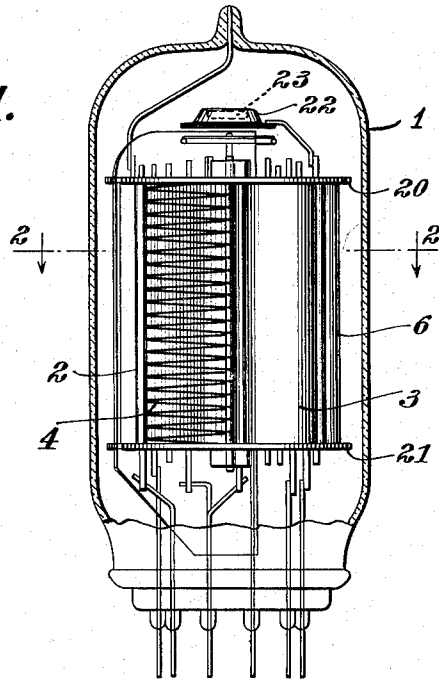
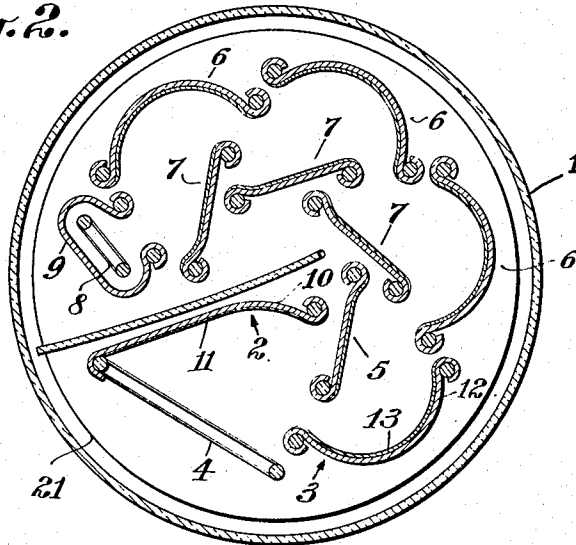


Fig. 2.



INVENTOR

Robert B. Janes

BY

Charles M. Claus
ATTORNEY

UNITED STATES PATENT OFFICE

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PHOTOELECTRIC ELECTRON MULTIPLIER

Robert B. Janes, Verona, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application October 8, 1940, Serial No. 360,255

9 Claims. (Cl. 250-175)

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My invention relates to photoelectric electron multiplier tubes and the method of manufacturing such tubes, and particularly to such tubes containing within a single envelope a photoelectric cathode and one or more secondary electron emitting electrodes.

Metals such as antimony, arsenic and bismuth have been photosensitized by evaporating one of these metals and condensing the metal from the vapor stage upon a foundation, whereupon, prior to oxidation, the condensed metal is treated with alkali metal as described in my U. S. patent application Serial No. 342,199, filed June 25, 1940. Such photocathodes are satisfactory for use in tubes of the photoelectric type, but considerable difficulty has been experienced in adapting such cathodes for use in photoelectric electron multipliers wherein the photoelectrons emitted by the cathode are successively multiplied by impingement upon secondary electron emitting electrodes. In such tubes of the latter type it is very difficult to separate the processes of photosensitization from the processes of secondary emissive sensitization because the electrodes being in a common envelope are subjected to the same atmosphere and to substantially the same treatment irrespective of the desired photo-emissive and secondary-emissive properties.

It is an object of my invention to provide a method of manufacturing photosensitive secondary electron multiplying tubes wherein both the photocathode and the secondary electron emitting electrodes are constructed and treated by a common process so as to obtain high sensitization. It is a further object of my invention to provide a tube of the type described having high photosensitivity and high secondary electron emissivity and in which these objects may be obtained with similar treatment; and it is a still further object to provide a tube wherein a single process of sensitization produces optimum photosensitivity of the cathode and optimum secondary electron emissivity of the secondary electron emitters. These and other objects, features, and advantages of my invention will be apparent when taken in connection with the following description of my invention and the accompanying drawing, in which,

Figure 1 shows a type of tube to which my invention is particularly directed; and Figure 2 shows an enlarged cross-section of the tube of Figure 1 taken along the lines 2-2.

In accordance with my invention I provide foundations for the photosensitive and secondary electron emitting structure wherein the quantity of antimony, arsenic, or bismuth on the foundation of these electrodes is so chosen that subse-

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quent treatment with an alkali metal such as caesium produces optimum photosensitivity of the photocathode and optimum secondary electron emissivity of the secondary electron emitting electrodes. More particularly, and in accordance with my invention, I provide a coating of antimony, arsenic, or bismuth of a predetermined thickness on the photocathode foundation and a coating of the same metal from this group but of a different thickness than the predetermined thickness on the secondary electron emitting electrode foundations so that when sensitized by a common sensitizing treatment, optimum photosensitivity and optimum secondary electron emissivity will result. While I will describe my invention with respect to the use of antimony and caesium in a particular type of tube, it is to be understood that I am not limited to the particular type of structure described, my invention broadly relating to all tubes having photocathodes and secondary electron emitting electrodes and to such tubes having electrodes comprising antimony, arsenic, or bismuth sensitized with an alkali metal.

Referring to the drawing, I provide a tube shown in Figures 1 and 2 having a single envelope or bulb 1 enclosing both the photocathode and secondary electron emitting electrodes wherein the cathode 2 is supported to intercept light projected through the wall of the envelope and in a relationship with a secondary electron emitter 3 for the purpose of withdrawing the electron emission from the photocathode 2. To direct the electrons from the photocathode 2 to the secondary electron emitter 3 I provide a directing electrode which may be in the form of a coarsely wound grid 4 which is electrically connected to the cathode 2 so that electrons emitted therefrom are directed toward the secondary emitter 3. A further secondary electron emitter 5 is provided opposite the emitter 3 and it is well known in the art that an additional plurality of emitters 6 and 7 may be provided for further secondary electron amplification of the photo-emission from the photocathode 2. An anode 8 which may likewise be in the form of a wire mesh grid surrounded by an anode shield 9 is provided to collect the electron flow following the electron multiplication. My invention does not relate to the specific arrangement or structural details of the secondary electron emitters, but it has been found that the emitters 6 may be structurally similar one to the other and to the emitter 3, and likewise the emitters 7 structurally similar to each other and to the emitter 5.

In accordance with my invention the cathode 2 comprises a foundation 10 which may be of

nickel or other base metal carrying on its surface a thin film 11 of antimony, bismuth, or arsenic, the film being of predetermined thickness. This film will be referred to hereinafter as an antimony film and may be applied to a conducting foundation as described in my above copending application. The secondary electron emitter 3 is likewise constructed of a foundation 12 of metal such as nickel and likewise carries on its surface, which is to be secondary electron-emissive, a thin film 13 of antimony, but of a thickness greater than the thickness of the film 11 on the cathode 2. The secondary electron emitters 5, 6, and 7 are likewise provided with this thin film of antimony having a thickness greater than the thickness of the antimony film 11 on the photocathode 2.

The foundation for the various emitting electrodes may be provided with the film of antimony prior to their assembly in the evacuated envelope or bulb 1 by sealing the various electrode foundations in a separate envelope or bell jar provided with a source of antimony which may be heated, vaporized and condensed on the various foundations. I have found that the thickness of the antimony film on photocathode 2 is preferably about 500 angstroms (A.), whereas I have found the thickness of the antimony film on the secondary emitter foundations to be preferably twice as great, or approximately 1000 A. The thickness of the antimony films may be determined by the amount of antimony evaporated. Thus, to obtain an antimony film of 1000 A. thickness, I have evaporated 160 milligrams of antimony supported on a tungsten filament along an axis surrounded by a group of the electrode foundations to be coated and at a distance of $3\frac{1}{2}$ " from the antimony-bearing filament. Similarly, the evaporation of 80 milligrams of antimony will produce a film of 500 A. thickness when surrounded by one or more cathode foundations at a similar distance. It is apparent from Figure 2 that the cathode 10 is relatively flat, whereas the emitters 3 and 6 are arcuate-shaped and the evaporation of the antimony or other metal thereon may be done prior to the shaping of the electrode foundations although for electrodes having considerable area it is desirable to pre-form the foundations so that they are arcuate-shaped with their centers of curvature at the source from which the antimony is evaporated.

Following the condensation of antimony to a different thickness on the photocathode foundation with respect to the thickness on the secondary emitter foundations, I support the electrodes within the envelope 1 between two supports 20 and 21 which may be of mica perforated to accurately position the electrodes. Following the assembly, the envelope 1 is evacuated to a high degree of vacuum and the entire assembly and tube baked at a temperature of 150° C. for a period of from 4 to 10 minutes although I have found that this baking step may be omitted with substantially no injurious effects. Following the baking step, if not omitted, and prior to any oxidation whatsoever of the antimony films, I vaporize alkali metal within the envelope such as by heating a tab 22 containing an alkali metal or compound in the form of a pellet 23, such as by high frequency induced currents. In accordance with my prior teaching and throughout the vaporization of the alkali metal I maintain the temperature of the antimony coated electrodes at such a temperature as to cause an alloying of

the alkali metal with the antimony films 11 and 13. The temperature to produce such alloying of the alkali metal with the antimony may vary over wide limits extending from room temperature up to 200° C. and since all of the electrodes are within a single envelope they are maintained at substantially the same temperature. The evidence that an alloy of antimony and caesium is formed resides in the fact that the antimony film prior to the vaporization or introduction of caesium in vapor form within the envelope has substantially no photosensitivity and the secondary electron emissivity of the secondary emitters is very low. Immediately upon the liberation of caesium, the photosensitivity of the cathode and the electron emissivity of the secondary emitters increases even when the bulb 1 is maintained at room temperature. The phenomenon of the cathode antimony film becoming photosensitive and the antimony on the secondary emitters becoming highly secondary-electron-emissive is believed to be due to the formation of the antimony-caesium alloy, and since the caesium condenses on the antimony films from the vapor stage in which state it is quite hot, this formation of an alloy apparently occurs even at room temperature. The caesium is preferably slowly evaporated and for this reason the pellet 23 may be located outside of the envelope in a separate tubulation for better control of the amount of caesium introduced within the bulb 1. Somewhat more uniform photosensitivity over the entire area of the cathode may be obtained by this latter method making possible a first condensation of caesium vapor on the wall of the tube followed by heating the wall to revaporize the caesium whereupon it condenses upon the antimony films. The evaporation and condensation may be likened unto a distillation process and is continued until the photoelectric sensitivity of the cathode has reached a maximum, following which the tube is baked in an oven to a temperature of 150 to 170° C. until the photosensitivity has reached a new and higher maximum. I have found some tubes to reach this second maximum following a baking of a few minutes, whereas other tubes require baking for several hours. Continued baking after a maximum sensitivity has been obtained does not harm the tube so that after sealing off the bulb 1 from the exhaust system a large quantity of tubes may be baked together in a large oven for a time sufficient for all of the tubes to attain maximum photosensitivity.

It may be noted that the above process is based on maximum photosensitivity as a reference. It is also possible and sometimes preferable to collect not only the photo-emission from the cathode 2 such as by maintaining the secondary emitters at a common potential, but to apply progressively more positive potentials to the secondary emitters, whereupon the amplified photo-emission is collected by the anode 8. This latter method may in some cases produce a better overall response, although tubes made in accordance with my invention produce optimum photo-emission and optimum secondary electron emission because of the predetermined thickness of antimony films used on the electrodes.

I have found for optimum photosensitivity and for optimum secondary electron emissivity that the ratio of caesium to antimony comprising the cathode should be higher than the ratio of caesium to antimony comprising the secondary emitter. This difference in the ratio of alkali

metal to antimony explains the greatly improved results of a tube processed in accordance with my invention. This improvement is due to the fact that the quantity of caesium per unit alloy volume or density of caesium in the antimony caseium alloy of the photocathode is greater than the density of caesium in the antimony alloy of the secondary emitter. With antimony films of different thickness the same amount of caesium may be used to obtain different caesium densities. I have found that in the range of antimony film thicknesses used and for optimum photosensitivity and secondary electron emissivity the amount of caesium absorbed by the antimony films is substantially independent of the film thickness. Thus per unit area the cathode film which preferably is about one-half the thickness of the secondary emitter film absorbs approximately the same amount of caesium as the secondary emitter film. The relative thickness of the films remains substantially the same but the caesium density of the cathode film is approximately twice the caesium density of the emitter film. Furthermore, while I have found for best results that the thickness of the antimony cathode film is approximately one-half that of the antimony secondary emitter film, I do not wish to be limited to this particular ratio. Depending on the amount of caesium used a condition may be reached at which the ratio of secondary emitter antimony film thickness to cathode film thickness may be as high as 3 to 1, or as low as 1.5 to 1. Furthermore, for greater or smaller amounts of caesium introduced into the envelope containing the electrodes, the thickness of the films may be correspondingly increased or decreased.

While I have described my invention in connection with the use of antimony, it is to be understood that I do not wish to be limited to this particular metal, since I have found arsenic and bismuth to be satisfactory as an equivalent of antimony. Therefore, while I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only certain specific applications for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

I claim:

1. An electron discharge device of the electron multiplying type including a cathode of a metal alloyed with an alkali metal and a secondary electron emitter of a metal alloyed with an alkali metal, the ratio of alkali metal to total alloy volume of said cathode being greater than the ratio of alkali metal to total alloy volume of said emitter.

2. An electron discharge device of the photocathode-secondary electron multiplier type comprising a photocathode of a metal selected from the group of metals consisting of antimony, arsenic, and bismuth alloyed with an alkali metal, and a secondary electron emitting electrode including an alloy of the same metals as said cathode, the density of the alkali metal in the alloy of said photocathode being greater than the density of alkali metal in the alloy of said secondary electron emitting electrode.

3. An electron discharge device including an antimony-alkali metal alloy photocathode and an antimony-alkali metal alloy secondary electron

emitter the amount of alkali metal per unit volume of said cathode alloy being greater than that of said emitter alloy.

4. A photoelectric electron multiplier comprising a single evacuated envelope, a cathode comprising an antimony caesium combination, a secondary electron emitter comprising an antimony caesium combination the ratio of caesium to antimony comprising said cathode being greater than the ratio of caesium to antimony comprising said secondary electron emitter.

5. A photoelectric electron multiplier comprising a cathode foundation and a secondary electron emitter foundation, a coating on said cathode foundation comprising a mixture of antimony and caesium, and a coating of antimony and caesium on said emitter foundation, the thickness of the antimony on said foundations differing in a ratio of substantially two to one.

6. The method of manufacturing a photoelectric device including a photoelectrically-sensitive cathode and a secondary electron emitter which comprises depositing a metal selected from the group of metals consisting of antimony, arsenic, and bismuth on a supporting foundation to a predetermined thickness depositing a similar metal from said group of metals on a second foundation to a thickness greater than said predetermined thickness and subjecting said foundations to alkali metal vapor to form alkali metal alloys having different densities of alkali metal.

7. The method of manufacturing a photoelectric device including a photocathode and a secondary electron emitter which comprises depositing to a predetermined thickness on a supporting foundation a metal selected from the group of metals consisting of antimony, arsenic, and bismuth, depositing a similar metal from said group of metals on a second foundation to a thickness substantially twice said predetermined thickness, sealing said foundations in a single envelope, evacuating the envelope, and subjecting said foundations to alkali metal vapor to form alkali metal alloys wherein the ratio of alkali metal to the metal selected from said group of metals is greater on said first-mentioned foundation than on said second foundation.

8. The method of manufacturing a photoelectric secondary electron multiplier which comprises forming a pair of electrode foundations having films of different thickness of metals selected from the group of metals consisting of antimony, arsenic, and bismuth, and subjecting said films to alkali metal vapor to form alkali metal alloys having different alkali metal densities.

9. The method of manufacturing an electron discharge device including a cathode and a secondary electron emitter which comprises forming a coating of antimony on a cathode foundation, forming a coating of antimony on a secondary emitter foundation to a thickness between one and one-half to three times the thickness of antimony on said cathode foundation, sealing each of said coated foundations within a single envelope, evacuating said envelope and simultaneously subjecting said coated foundations to alkali metal vapor prior to any step of oxidation thereof within said envelope to form an antimony alkali metal combination wherein the ratio of alkali metal to antimony comprising said cathode is greater than the ratio of alkali metal to antimony comprising said secondary emitter.