

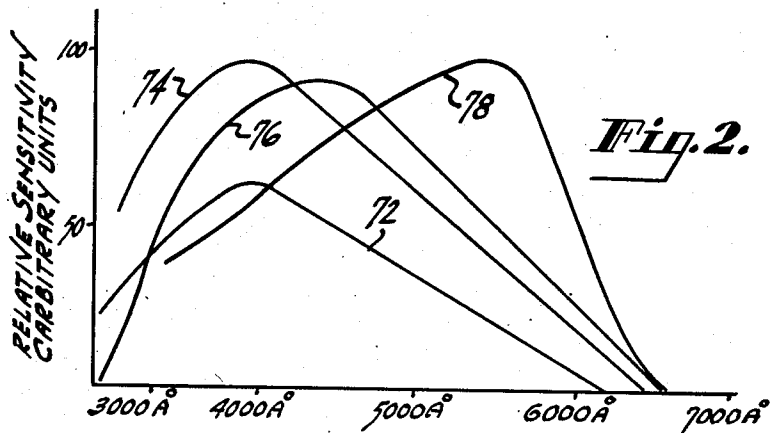
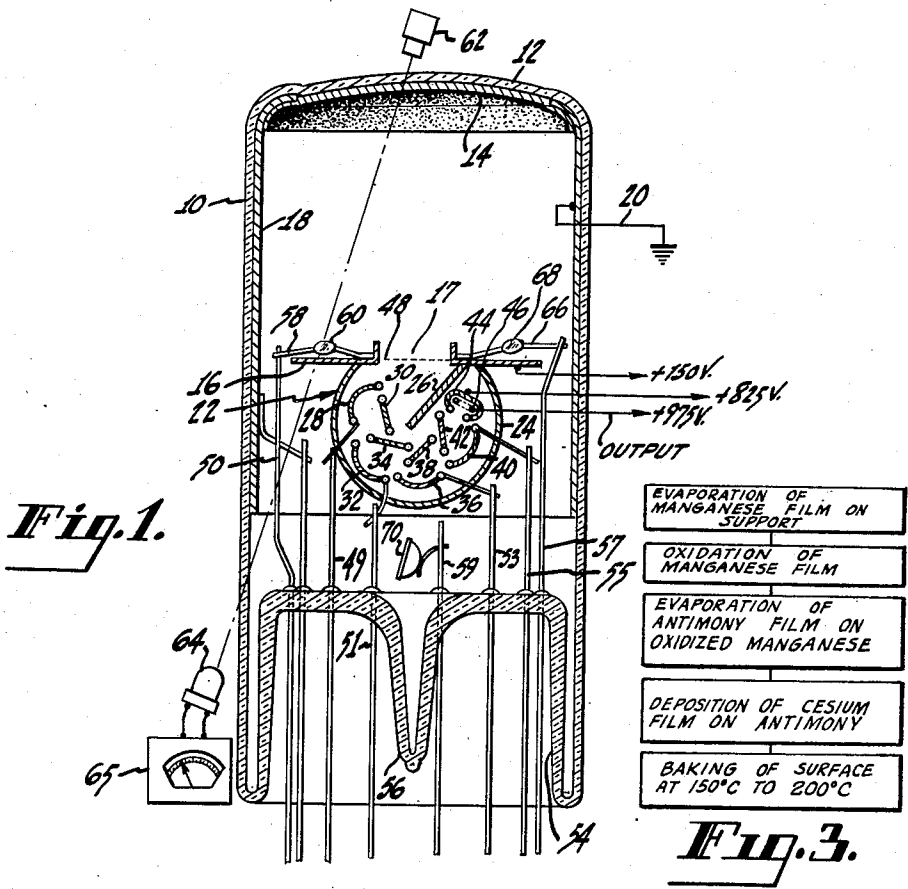
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PHOTOCATHODE FOR MULTIPLIER TUBES

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PHOTOCATHODE FOR MULTIPLIER TUBES

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This invention relates to a photosurface, and more specifically to a photoemissive cathode for use in phototubes, high vacuum photomultiplier tubes, or in pickup camera tubes for television.

Antimony films sensitized with cesium have been used as photocathodes in photomultiplier tubes. A semi-transparent cesiated antimony photocathode has a spectral response over a range from 3000 Å. to 6400 Å. The response of the material is peaked around 4800 Å in the blue with little response in the red. Although this photosurface has fair sensitivity it is desirable to increase its sensitivity as well as to provide a spectral response peaked more in the yellow and red regions of the spectrum. Such a spectral response would broaden the use of the photosurface in applications requiring such a response, such as pickup tubes having a red response for color television or for flying-spot, pickup systems using red luminescing phosphors.

It is thus an object of my invention to provide a photosensitive device having a cathode of improved sensitivity.

It is another object of my invention to provide a photosensitive device having a photocathode formed of antimony and cesium and having improved sensitivity.

It is another object of my invention to provide a photosensitive device having a photocathode formed from antimony and cesium and having improved sensitivity to red light.

Specifically my invention relates to a photosensitive device having an improved semitransparent photocathode formed by depositing antimony and cesium on a manganese oxide film. It is found that the sensitivity of such a photosurface is greater than related surfaces and that the spectral response is shifted toward the red by the degree of oxidation of the manganese film.

Figure 1 is a sectional view of a photoemissive tube having a photocathode formed in accordance with my invention. Figure 2 is a curve showing the relative sensitivity and spectral response of different photocathodes, formed in accordance with my invention. Fig. 3 is a flow-chart showing the steps in the formation of the photocathode.

Figure 1 discloses a photomultiplier tube which is intended for use in applications involving low-level, large-area light sources, such as scintillation counters used in the detection and measurement of nuclear particle radiations. The tube comprises essentially a glass envelope 10, closed at one end with a transverse wall section 12, upon which is formed a transparent photocathode sur-

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face 14. The envelope wall portion 12, in one tube of this type, has a diameter of approximately two inches, while the exposed portion of the photocathode film 14 is approximately 1½ inches.

This provides a useful, large, substantially flat cathode area which permits good optical coupling between the photocathode and a phosphor, used in scintillation counters, for example.

Spaced from the photocathode and along the tube axis is an accelerating electrode 16 formed as a disc having an aperture 17 at its center. A metallic wall coating 18 is formed on the inner surface of the tube envelope and extends from the photocathode film 14 axially down the tube to a portion below the accelerating electrode 16. Wall coating 18 provides electrical contact between the photocathode 14 and a lead 20 connecting the photocathode and the metallic film 18 to a source of ground potential, as shown.

As indicated in Figure 1, a potential difference of 150 volts is maintained as an operating value between accelerating electrode 16 and the photocathode 14. Photoelectrons emitted from cathode 14 are thus accelerated toward electrode 16. Wall coating 18 aids in directing the photoelectrons toward the opening 17, at the center of electrode 16. Also the shape of the envelope end-wall portion 12 tends to focus the photoelectrons into opening 17.

Photoelectrons passing through opening 17 are collected by an electron multiplier section 22, which consists of a plurality of dynode electrodes enclosed in a cylindrical metal shield 24. The photoelectrons will impinge upon a first dynode electrode 26 and will initiate secondary emission therefrom and having a ratio greater than unity. This secondary emission is accelerated and directed by a fixed electrostatic field along curved paths to a second dynode electrode 28, and from there to a third dynode electrode 30. In like manner, the secondary electrons from dynode 30 are directed onto successive dynodes 32, 34, 36, 38, 40, 42, and 44. Each dynode provides an amplification of the electrons striking it to form an ever-increasing stream of electrons, until those emitted by the last dynode 44 are collected by an anode electrode 46. Anode 46 consists of a grid so that electrons from dynode 42 will pass there-through to the final dynode stage 44 before collection. This type of electron multiplier is fully described in U. S. Patent 2,285,126 to Rajchman et al. The specified details of this multiplier do not constitute my invention. The current collected by anode electrode 46 constitutes the current utilized in the output circuit of the tube.

Opening 17 into the multiplier section 22 is covered by a mesh grid 43. This grid is connected electrically to the first dynode 26 and directs the secondary electrons from the dynode toward the second dynode 28. The grid also tends to prevent secondary electrons from dynode 26 from passing back toward the photocathode 14. The first dynode electrode 26 is fixed to the accelerating disc 16 and is thus tied electrically to it. During tube operation, a potential difference of about 75 volts is maintained between each of the succeeding dynode stages.

Commercial tubes, of the type described, have been made with a photosurface formed by putting down on the glass end wall 12, first, a semi-transparent film of antimony, and then a film of cesium. The photosurface is activated by baking the tube around 180° C. This type of photosurface has provided a spectral response between 4000 Å. and 6500 Å., with little red response. Furthermore, the sensitivity of such a photosurface, in commercial tubes, is relatively low, seldom exceeding 40 microamperes per lumen, from a tungsten lamp source at a filament color temperature of 2870° K. This photosurface is primarily sensitive to blue light. In some applications it has been desirable to broaden the spectral response of the photosurface particularly for use with light sources having emission in the yellow and red regions of the spectrum. Furthermore, it is desirable that the sensitivity of the photosurface be increased to enable the photosurface to be used with low-level light sources, and to increase the signal to noise ratio.

In accordance with my invention, I have found that if a manganese oxide film is formed on the glass end wall 12 of the tube, prior to the deposition of the antimony film, that not only will the sensitivity of the tube be greatly increased, but also the spectral response of the tube will be shifted toward the red end of the spectrum. Furthermore, the amount of the shift can be controlled by the degree of oxidation of the manganese film. Sensitivity as high as 80 microamperes per lumen to tungsten light at 2870° K. have been obtained with this new photosurface.

The manganese oxide film may be formed in several different ways on the surface of the glass end wall 12. However, evaporation of the manganese in vacuum followed by oxidation of the resulting manganese film has proved to be the most satisfactory method.

The tube of Figure 1 is conventionally formed by mounting the electrode structure consisting of accelerating electrode 16 and the multiplier section 22 on a plurality of lead pins 49, 51, 53, 55, sealed through a flared glass press portion 52. The press 52 consists of a reentrant portion 54 and an exhaust tubulation 56. The electrode structure is mounted on the press 52 by welding short leads from the electrodes to the lead pins respectively. The envelope portion 10 is first coated with the conducting film 18, by evaporating a material, such as aluminum, in a vacuum, to make electrical contact with the cathode. During the evaporation of the aluminum, a mask or shield is placed over the end wall 12 to prevent the deposition of aluminum on the glass of the end wall. The glass press portion 52, with the electrode structures mounted thereon, is then inserted into the open end of envelope 10 and skirt portion 54 is sealed to the end of the envelope portion 10.

The photosurface 14 is made in accordance with the following procedure. The oxidized

manganese film, of the photosurface 14, may be formed on the uncoated portion of the end wall 12 either before or after the electrode mount structure is sealed into the envelope. The method of formation in both cases is similar. It has been found, however, that it is an advantage to oxidize the manganese film after sealing the mount structure into the tube and because the manganese oxide appears to take up water vapor, if it is exposed to the atmosphere before the tube has been sealed. Before sealing the electrode mount structure into envelope 10 a filament 58 is welded to a lead 50 and to the accelerating electrode 16, as shown. Filament 58 is a tungsten wire, to which is fixed a pellet 60 of pure manganese metal. The pellet may be commercial electrolytic manganese, consisting of pure manganese having a maximum of 0.1% of sulfur and iron.

After the glass press 52 has been sealed to the envelope 10, the exhaust tubulation 56 is connected to an exhaust system (not shown) and the tube evacuated. All of the tube then is baked-out in an oven at between 260° C. and 280° C. for half an hour, after which the tube is cooled to room temperature. In order to form the photosurface 14, a light source 62 is arranged above the tube end wall 12 and light directed through the envelope onto a photoelectric tube 64 which is connected to an amplifying device 65 having a graduated dial indicating a current flow proportional to the amount of light from source 62. The indicator can be adjusted to show a scale reading of 100 at full transmission of the light through the envelope. While the envelope 10 is still evacuated, a current is passed through filament 58 to heat and evaporate the manganese pellet 60. The evaporated manganese will condense upon the adjacent envelope wall portion and form a thin coating on the end wall 12. The manganese metal is evaporated until the light transmission from source 62 through the envelope has been reduced to 90% as indicated by device 65. This thickness of the manganese film is not critical and improved sensitivity is obtained with layers as thick as 50% transmission or as thin as 95% transmission. Oxygen is next introduced into the bulb through the exhaust tubulation 56, to a pressure of about 700 microns of mercury. The transparent manganese film is then oxidized by the use of a high frequency wand placed over the end wall 12. The high frequency potential of the wand produces within the envelope 10 a gaseous discharge which causes the manganese to react with the oxygen in the envelope. The wand is moved over the end wall 12 for about two seconds. This method of oxidizing metal films within an envelope is well known and fully described within U. S. patent to Essig, 2,020,305. The oxygen within the envelope is then removed and the reading of indicator 65 is reset to 100. An antimony film is next put down over the oxidized manganese surface, also by evaporation of the antimony in vacuum. A tungsten-molybdenum filament 66 is provided between one of the leads 50 and the accelerating electrode 16. Fixed to the filament 58 is an antimony pellet 68. The antimony may be high grade commercial antimony having a composition substantially 99.98% antimony and traces of iron, sulfur, arsenic and lead. Passing a current through filament 66 evaporates the antimony pellet and provides a film over the oxidized manganese deposit on the end wall 12. The evaporation of the antimony is continued until the light transmission through the end wall 12 is

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approximately 50%. Cesium is then released into the evaporated envelope by heating, with a high frequency coil, a small metal container 70 mounted on a lead wire 59. The cesium permeates through the envelope and deposits over the antimony film on the end wall 12. The cesium is evaporated for approximately 7 seconds to provide a sufficient amount of the metal. The tube is then baked in an oven, at a temperature between 150° C. and 200° C., to promote an activating reaction between the cesium, antimony and oxidized manganese base.

A photosurface made in accordance with the described method and using an oxidized manganese film has provided consistently good sensitivity and as high as 80 microamperes per lumen.

It has been found that the amount of oxidation of the manganese film tends to control the shift of spectral response from the blue toward the red. Figure 2 discloses several curves relating to photosurfaces using a manganese oxide film and made in accordance with my invention. In Figure 2, the relative sensitivity in arbitrary units is plotted against wavelength in Angstrom units. Curve 72 represents substantially the sensitivity and spectral response of photosurfaces formed of antimony-cesium deposited upon an unoxidized manganese metal film. Curves 74, 76, and 78 represent photosurfaces formed of antimony and cesium films deposited upon a film of oxidized manganese metal, and with increasing oxidation of the manganese metal respectively. It is apparent from the curves, that the oxidation of the manganese film provides, first a significant increase in the sensitivity of the photosurface. Furthermore, as the amount of oxidation of the manganese takes place, the peak spectral response shifts from the blue into the green and yellow portion of the spectrum.

The novel photosurface has been described above in connection with a photomultiplier tube. However, the use of such a photosurface need not be restricted to this type of tube. The novel photosurface may be used also successfully in a simple phototube in such applications as colorimetry, where colors are matched as for example in selecting of colored yarns or in chemical titration, for example. By the process of selective oxidation, as described above, such a photosurface can be peaked at around 5500 Å. and by using a blue filter, the response of the photosurface can be

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adjusted to closely correspond to that of the eye. Such a photosurface would have applications in pick-up tubes for television, such as the Image Orthicon for example and as disclosed in the co-pending application of R. E. Johnson, Serial No. 79,328, filed March 2, 1949. A red responsive phototube made in accordance to my invention may also be adapted for color pickup tube applications.

From the foregoing, it will be apparent that the present invention provides an improved antimony-cesium photocathode and one characterized by its improved sensitivity and color response.

What is claimed is:

1. A photosensitive cathode comprising, a transparent support base element, an oxidized manganese film on said base element, a deposit of antimony on said oxidized manganese film, and a deposit of cesium on said antimony film.

2. A phototube comprising, a transparent support member, an anode electrode spaced from one surface of said support member, a photocathode formed on said support member, said photocathode including an oxidized manganese film on said one support surface, a deposit of antimony on said oxidized manganese film, and a deposit of cesium on said antimony.

3. The method of making a photosensitive surface on a transparent foundation, said method comprising the steps of, depositing a manganese metal film upon the surface with a light transmission therethrough between 50° and 95°, oxidizing said manganese film, and successively depositing antimony and cesium metal on said oxidized film.

4. The method of making a photosensitive surface on a transparent foundation, said method comprising the steps of, depositing upon a surface of the foundation a manganese metal film having a light transmission therethrough of 90°, oxidizing said manganese film, depositing antimony metal on said oxidized manganese film until light transmission through said photocathode surface is substantially 50%, and depositing cesium metal on said photosurface.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
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2,218,340	Maurer	Oct. 15, 1940