

June 29, 1954

R. E. JOHNSON
PHOTOSURFACE OF A PANCHROMATIC TYPE
AND METHOD OF PREPARING SAME

2,682,479

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2 Sheets-Sheet 1

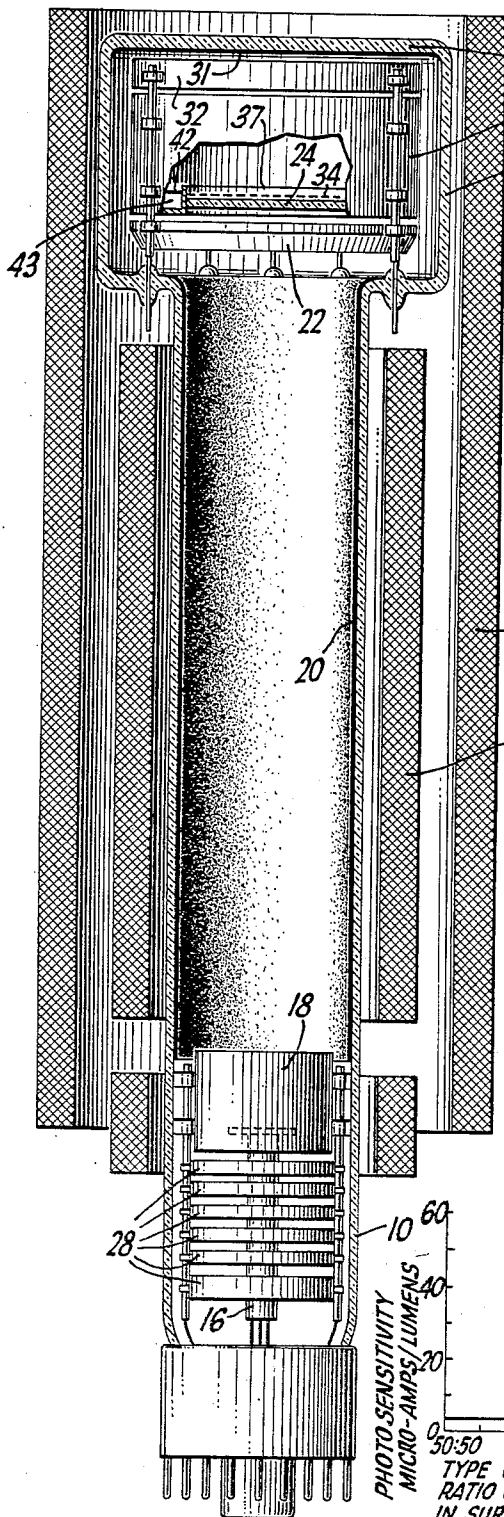


Fig. 1

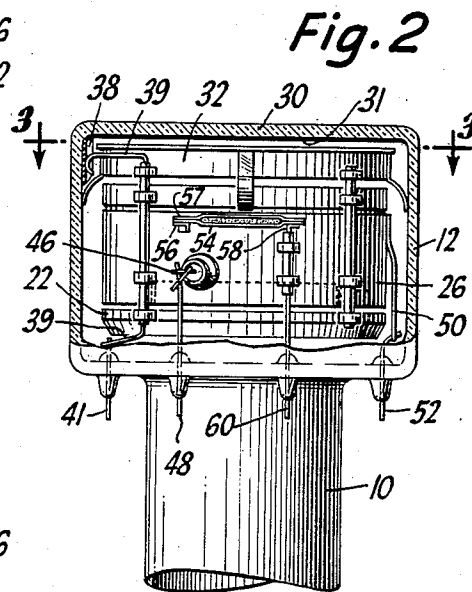


Fig. 2



Fig. 6

Fig. 3

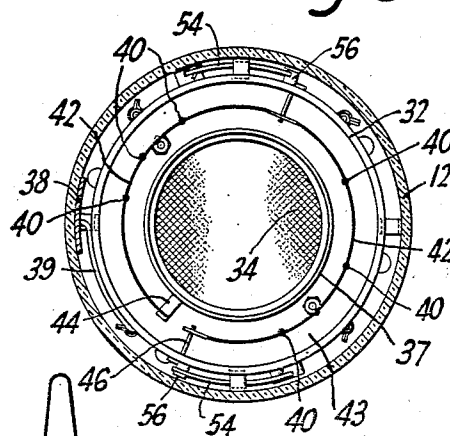
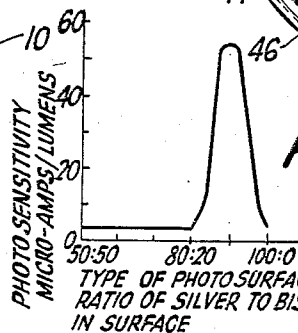


Fig. 5



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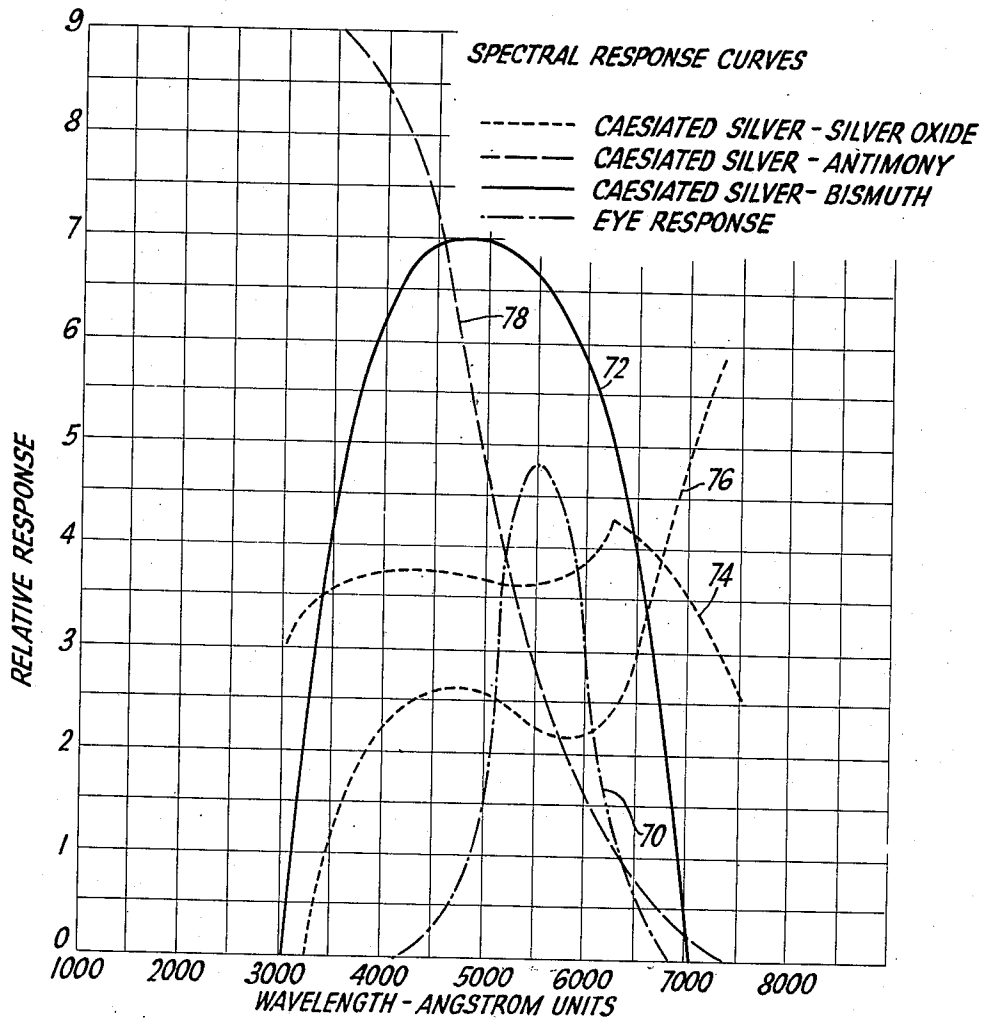
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Fig. 4



NOTE:-

CURVES SHOW RELATIVE RESPONSE OF EACH SURFACE TO RESPECTIVE WAVELENGTHS OF ENERGY. RELATIVE HEIGHT OF CURVES FOR DIFFERENT SURFACES ARE NOT DIRECTLY COMPARABLE TO DETERMINE RELATIVE RESPONSE OF DIFFERENT SURFACES.

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UNITED STATES PATENT OFFICE

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PHOTOSURFACE OF A PANCHROMATIC
TYPE AND METHOD OF PREPARING
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11 Claims. (Cl. 117—33.23)

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This invention relates to the method of making a photoemissive surface of general application, but having a particular use in television camera tubes.

One type of television camera pickup tube utilizing the novel photoemissive surface formed according to my invention, is that having an image section consisting of a photocathode electrode formed on the end plate of the tube envelope and a thin glass target electrode spaced from the photocathode. An optical image focussed upon the photocathode releases a photo-emission which is accelerated and focussed so that it strikes the thin glass target electrode with an energy sufficient to cause a secondary emission from the glass surface greater than unity. The secondary emission leaves a positive charge pattern on the glass target surface corresponding to the optical image focussed upon the photocathode. The opposite side of the glass target is scanned by an electron beam which is caused to approach the target at close to zero velocity. Due to the extreme thinness of the glass target, the electrostatic image on the one side of the target sets up the same image potential on the scanned side of the target. Electrons from the scanning cathode ray beam will be drawn to the positive areas of the target surface and will be deposited on the target to neutralize the positive potential pattern on the glass. The deposited beam electrons discharge the target surface to cathode potential at which point the remainder of the beam is reflected back along the path and is collected to form video signal of the tube.

In the type of television camera pickup tube described above, two different photoemissive surfaces have found application. One photosurface is formed from a silver-antimony alloy which is sensitized with caesium. This photosurface has low response to infra-red, a desirable characteristic, and the colors of the visible spectrum are reproduced in a reasonably satisfactory manner under controlled conditions of illumination and lighting. However, this silver-antimony photosurface has a relatively low sensitivity of approximately 6 microamperes per lumen. A television camera pickup tube utilizing this photosurface is used mainly with controlled lighting or where intensity of illumination is sufficiently high. Another type of photosurface is formed from silver-

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silver oxide sensitized with caesium, which has a greater relative sensitivity of approximately 20 microamperes per lumen. This silver-silver oxide photosurface is very stable in performance at all light levels ranging from bright sunlight to that of deep shadow. However, the caesiated silver-silver oxide photosurface has too great an infra-red response, so that colors are not reproduced faithfully, i. e. as the human eye sees them, giving an unnatural appearance to the television picture. If one attempts to use filters to correct the response, the sensitivity is reduced to that of the silver-antimony photosurface or less.

The silver-antimony photosurface, as suggested above, is better adapted to controlled lighting conditions, while the caesiated silver oxide photosurface will be sufficiently sensitive for use in television tubes under natural lighting conditions of outdoors. Because of this, it is necessary to use two different camera tubes in order to televise the whole range of lighting conditions which may be required. Furthermore, when using two different camera tubes, the pictures from outdoor or poorly lighted sets do not match those transmitted from the studio, where controlled lighting is possible, resulting in an additional objection from an artistic point of view. Therefore, a very desirable feature in a photosensitive surface used specifically for television camera pickup tubes would be to have a color spectral response matching that of the human eye and also having a maximum sensitivity permitting such a camera tube to be used under all conditions of lighting.

It is an object of my invention to provide a photoemissive surface of great sensitivity.

It is another object of my invention to provide an improved photoemissive surface having high spectral response throughout the visible region.

It is a further object of my invention to provide an improved photoemissive surface having spectral response similar to visual response.

It is a further object of my invention to provide an improved photoemissive surface with negligible response outside the visible region.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the inven-

tion itself will best be understood by reference to the following description taken in connection with the accompanying drawing, in which:

Figure 1 discloses a type of television camera pickup tube utilizing a photosurface made according to my invention.

Figure 2 is an enlarged view of the image section end of the tube shown in Figure 1.

Figure 3 is a view of the image section shown in Figure 2 and viewed in the direction of the arrows 3—3 of Figure 2.

Figure 4 is a graph showing relative responses of various photosurfaces as compared with that of the novel photosurface made according to my invention.

Figure 5 is a graphical representation of the photosensitivity of a series of photosurfaces made according to my invention.

Figure 6 is an enlarged sectional view of the photocathode of the tube of Figure 1 in accordance with the invention.

The particular photosensitive layer which is the subject of my invention may be applied to any desired supporting surface which may be either opaque or transparent. The specific use of my new photosurface is in television camera pickup tubes either of the image orthicon type in which a transparent photocathode is used, or in an iconoscope in which the photocathode is opaque and the scene is focussed upon the same side of the photocathode electrode as is scanned by the electron beam.

In Figure 1 is disclosed a television camera pickup tube utilizing a photoemissive surface made according to my invention. In operating the tube of Figure 1, a scene which is to be televised is focussed upon the end plate 30 of the tube envelope 10. Photoelectrons are released from a semi-transparent photoemissive surface 31, formed on the inner surface of the face plate 30. The photoelectrons are accelerated by a ring electrode 32 so that they will strike a thin glass target 24 with sufficient energy to cause a secondary emission greater than unity from the surface of glass 24. An electro-magnetic coil 36 surrounding the envelope 10 provides a field coaxial with the tube envelope 10 for focussing the photoemission upon the glass target 24. A fine mesh screen 34 is closely spaced from the surface of target 24 and functions as a collector electrode of the secondary emission. The secondary emission from the surface of the glass target 24 leaves a positive charge pattern on the glass target surface corresponding to the optical image focussed upon the photocathode 31. The opposite side of the glass target 24 is scanned by an electron beam formed by an electron gun structure represented at 16. The electron beam is caused to approach the opposite surface of target 24 at close to zero velocity through the use of a decelerating electrode 22. Due to the extreme thinness of the glass target 24, the electrostatic emission on the photocathode side of the target 24 sets up the same image potential on the side of the target 24 scanned by the electron beam. Electrons from the cathode ray beam will be drawn to the positive areas of the target surface and will be deposited on the target to neutralize the positive potential pattern on the glass 24. The deposited beam electrons discharge the surface of glass target 24 to cathode potential at which point the remainder of the beam is reflected back along toward the gun structure 16. This return beam is amplified by passing it through a multiplier section 28 in which it is

finally collected to form the video signal of the tube.

As shown in Figure 2, the photoemissive surface 31 of the tube of Figure 1 is connected to an external circuit through a silver stripe 38 in contact with the layer 31 and a lead 39 connected between stripe 38 and a stem pin 41.

To form my improved photosurface, an alloy of pure silver and pure bismuth is made up by weight in the ratio of 9 parts of silver to 1 part of bismuth. The mixture is heated until melted and is continuously stirred until the metals are well mixed together. Upon cooling, the material forms an alloy mass. The silver-bismuth alloy may be put down upon the supporting target surface in any desired manner. A satisfactory method is that of evaporating the alloy from heated filaments, made from a molybdenum-tungsten alloy. For example, as shown in Figure 3, small quantities 40 of the silver-bismuth alloy may be attached to an evaporator filament 42 by melting the silver-bismuth alloy and applying it to filament 42 at temperatures below evaporation. The melted silver-bismuth alloy tends to wet the filament wire 42 and will cling to the wire as a globule 40 and be firmly attached upon cooling.

During the assembling of the tube of Figure 1, filament 42 with the silver-bismuth alloy globules is mounted within the cylindrical electrode 26 and beyond the peripheral edge of the mesh 34 as shown in Figure 3. One end of the filament 42 is connected to a lead 46 (Figures 2 and 3) connected to a stem pin 48 passing through the envelope wall as shown. The other end of the filament 42 is connected at 44 to electrode 26 which can be connected externally of the envelope through lead 50 and stem pin 52. In this manner, filament 42 is mounted within the envelope 10, close to the face plate 30, upon which the photosurface 31 is to be formed. Two or more evaporators may be arranged symmetrically about the axis of the supporting surface 30, in place of the single filament 42.

The tube 10, in which the photosurface is to be formed, is first processed and evacuated, and then baked between 375°-400° C. for one hour to remove occluded gasses from the envelope. The metal electrodes within the tube are then heated and degassed, as is well known in the art. Also, if the tube has a thermionic cathode, this is activated at this point. After this normal processing of the tube, an electric current is passed through the evaporator filament 42 by the use of lead pins 48 and 52 to heat the filament to a temperature sufficiently high for evaporating the silver-bismuth alloy layer 31.

In forming the photocathode surface on the transparent face plate 30, the evaporator 42 is operated to deposit sufficient silver-bismuth alloy material to change the light transmission through plate 30 to 38% of the normal light transmission through supporting plate 30 before any film is deposited. This can be easily determined by passing a beam of light through the face plate 30 and causing it to impinge upon a photocell connected to appropriate circuits. As the silver-bismuth alloy is deposited upon the surface, the current flowing through the photocell is continuously indicated and the evaporation is stopped when the current has dropped to 38% of its initial reading.

After the silver-bismuth alloy is deposited on the supporting surface 30, it is oxidized until the light transmission through the transparent sup-

port 30 is raised to 50% of the normal or initial transmission of light prior to the putting down of the alloy layer. The oxidation step may be performed in any manner. One successful method is to admit oxygen into the tube envelope to a pressure between 300 and 500 microns. The silver-bismuth alloy film is then oxidized by a glow discharge produced within the tube and adjacent the supporting surface. The discharge is produced in a manner described in U. S. Patent 2,020,305 to Essig, in which a portable electrode is used and which is connected to one terminal of a radio frequency oscillator circuit, the other terminal of which is grounded. The portable electrode is slowly passed over the silver-bismuth surface several times until the light transmission becomes as stated above. During this step, a blue discharge is necessary to provide the proper conditions of oxidation. After oxidation of the silver alloy film, a layer of caesium metal is deposited upon the oxidized alloy film to provide photosensitivity of the layer. The step of depositing caesium may be done in any well known manner, and as described below.

To provide a source of caesium to caesiate the silver-bismuth photosurface 31 in the tube of Figures 1, 2 and 3, a mixture of caesium chromate and silicon, as a reducing agent, is placed into a pair of channels 54, which are mounted as is shown in Figures 2 and 3 on the outer surface of electrode 26. The channels are metallic and are formed as hollow troughs to hold the mixture of caesium chromate and silicon with suitable binding material to keep the material securely in the channel. One end of each channel 54 is attached as shown at 56 to the wall of the electrode 26, customarily by welding. The two metallic ends of each channel have been previously formed as extensions 57 so that the caesium activator mixture is confined to the hollow trough of the channel and does not interfere with this latter welding operation. The other end of each is connected to a lead member 58 which may be an extension of the stem pin 60.

After the previously described step of oxidizing the silver-bismuth surface 31, an electric current is passed through the stem lead 52 and 60 to heat the channel 54 to a sufficiently high temperature to cause a chemical reaction in the chromium-silicon mixture which will release pure caesium as a vapor in the photocathode end of the evacuated envelope 10. During this evaporation of the caesium metal, the tube 10 is maintained between 150° C. and 200° C. by being placed within an oven. This temperature of the tube maintains the caesium metal in vapor form and allows it to pass over onto the oxidized silver-bismuth alloy surface and combine uniformly with the semi-transparent metallic layer. The caesium metal vapor is caused to be deposited upon the silver-bismuth alloy surface 31 until the alloy surface provides maximum photo-sensitivity. This may be determined by illuminating the photosurface with light during the evaporation of the caesium metal. An ammeter in the photocathode circuit of the tube is watched until it registers a maximum photoemission. When this occurs the current through the channel is stopped by turning off the applied voltage and evolution of caesium ceases. This method is sufficiently precise so that very little caesium beyond that necessary to properly sensitize the photosurface is introduced into the tube. Excess caesium, if any, will harmlessly be absorbed by the other parts or pumped out through the exhaust tubulation as the tube is still

sealed to an exhaust system for this operation. The above method of putting down a sensitized silver-bismuth alloy photosurface has been described mainly in connection with the formation of a photocathode on a transparent support. However, it is also possible to form a photosurface upon an opaque support member by a similar method.

The above method of making a photosensitive surface was described as using a silver-bismuth alloy consisting by weight of 90% of silver, and 10% bismuth. Photosurfaces formed in the manner described above and formed by an alloy having a silver to bismuth ratio of 90 to 10, have been found to have a sensitivity varying between 36 microamperes per lumen and 72 microamperes per lumen and have averaged around 53 microamperes per lumen. It is not necessary, in making a photoemissive surface according to my invention, to be limited to the silver to bismuth ratio of 90 to 10, as good photoemissive surfaces have been made with silver to bismuth ratios by weight of 92.5:7.5, 93.5:6.5 and of 95 to 5. Photoemissive surfaces made in the manner described above and laid down from a silver bismuth alloy having a ratio of the weight of silver to bismuth equal to 93.5:6.5 have been consistently good and have averaged around 45 microamperes per lumen. A series of photoemissive surfaces made with a silver to bismuth weight ratio of 95:5 have shown a range of sensitivities between 36 microamperes per lumen to 76 microamperes per lumen, averaging around 52 microamperes per lumen. Above this ratio of silver to bismuth, the sensitivity of the photoemissive surface appears to drop off. Tubes made with a silver bismuth photosurface having a ratio of weight of silver to bismuth of 97.5:2.5 show an average of around 10 microamperes per lumen, while photoemissive surfaces made entirely of silver with no bismuth alloyed therewith, and according to the method described above, have relatively poor photosensitivity of around 5 microamperes per lumen or less, and/or have undesirable spectral response characteristics as previously mentioned. Furthermore, photoemissive surfaces made with a silver to bismuth weight ratio of 80 to 20, according to the method described above, also have relatively poor sensitivity, which ranges from 2 microamperes per lumen to 5 microamperes per lumen. Photoemissive surfaces made with a lower proportion of silver than 80% have consistently shown poor sensitivity, for example, photosurfaces formed from an alloy having a silver to bismuth weight ratio of 50:50 have sensitivities ranging between 2 microamperes and 5 microamperes per lumen. From experimental data, it appears that there is an optimum range for the silver to bismuth weight ratio lying within the values of 80 to 20 and 98 to 2.

Figure 5 is a rough representation of the results obtained from a series of photoemissive surfaces made according to the method described and from varying proportions of silver to bismuth in the metal alloy used for the photosurface. The curve of this figure represents the values of the various photosurfaces described above. It is easily seen from the figure that maximum photoemission is obtained from those photosurfaces formed from alloys having ratios of the weight of silver to the weight of bismuth lying between 85:15 and 95:5 while a useful range is obtained from photosurfaces having silver to bismuth weight ratios lying in the range from 80:20 and 98:2. Furthermore, as described

above, it has also been determined that some photoemissive sensitivity is obtained from practically the whole range of values for the weight ratio of silver to bismuth from 50:50 to 100:0.

The novel photosensitive surface described above is one which provides a color response as shown in curve 72 of Figure 4, which is very similar to the response of the human eye, as shown by curve 70. The similarity of the two curves 70 and 72 is even more noticeable when considered with curves 74 and 76 which respectively represent spectral responses of two above-described, caesiased silver-silver oxide photosurfaces and also with curve 78 representing the spectral response of caesiased silver-antimony alloy photosurface. Although the caesiased silver-silver oxide type of photosurface has a relatively high sensitivity of around 20 microamperes per lumen, it can be seen from the curves 74 and 76 of Figure 4, that the color response of this type of photosurface extends far beyond the red region of the invisible spectrum and a great amount of its sensitivity is derived from its response to infra-red energy. This energy is present in nearly all practical scene illuminations to a greater or lesser extent but is not received as visible energy by the human eye.

Camera tubes using these caesiased silver-silver oxide photosurfaces, therefore, introduce what is known in the industry as "color masking." That is, they respond and give indication of light where the eye sees none, masking out the true color gradations seen by the eye. This results in the transmission of very unnatural-looking pictures, which is undesirable in television practice. Furthermore, as may be seen from curves 74 and 76, it has been very difficult to produce similar response characteristics among individual tubes employing this surface. That is, the spectral response of the silver-silver oxide surface is subject to appreciable variations due to factors that are not under control even by those skilled in the art. Consequently, in addition to every surface exhibiting response characteristics unsuited to television, individual tubes vary in their relative response to red and infra-red energy so that it is very difficult to get tubes with this type surface to match each other.

The spectral response for a caesiased silver-antimony alloy photosurface is illustrated by curve 78. This response can be duplicated fairly well from tube to tube and, although it possesses extremely high sensitivity to blue light compared to the eye response, the tonal response to color is not too objectionable because it is essentially confined to the visible spectrum. However, the sensitivity of such surfaces is too low to be used universally, so that where light levels are inadequate, a camera tube employing the silver-silver oxide surface must be employed.

From the curves shown in Figure 4, it can be easily seen that the novel silver-bismuth photosurface follows the normal eye response in all wave lengths much more closely than the other types of the photosurfaces which are in use in television camera pickup tubes.

Furthermore, this sensitized silver-bismuth photosurface has exceptional sensitivity, which is on an average higher than any other photosensitive material used in television camera tubes.

As described above, this silver-bismuth alloy photosurface has a sensitivity averaging above 50 microamperes per lumen. Due to this great sensitivity, television camera tubes using this

silver-bismuth alloy photosurface are capable of televising scenes under any lighting conditions encountered in a practical sense. Furthermore, the sensitivity of this photosurface is achieved while at the same time approaching the eye sensitivity curve more closely than any of the other surfaces known to the art. Because of the higher sensitivity and improved spectral response, filters may be used under certain conditions to approach the eye response curve even more closely without seriously affecting the performance of the tube. Because of these very decided advantages, the silver-bismuth photosurface has found extensive use in television cameras under all conditions, indoors, out-of-doors, and under television studio conditions. Television pickup tubes using this silver-bismuth photosurface produce better quality pictures with a higher degree of uniformity than has been achieved previously.

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. A photosensitive electrode comprising, a support, a layer of silver-bismuth alloy on the surface of said support, and a deposit of alkali metal on said alloy layer.

2. A photosensitive electrode comprising a support, a layer of oxidized silver-bismuth alloy on a surface of said support, and a deposit of alkali metal on said oxidized alloy layer.

3. A photosensitive electrode comprising a support, a layer of oxidized silver-bismuth alloy on a surface of said support, and a deposit of caesium on the surface of said alloy layer.

4. A photosensitive electrode comprising a support, a film on one surface of said support including an alloy of silver and bismuth combined with oxygen and caesium.

5. A photosensitive electrode comprising a film on a surface of said support including an alloy of silver and bismuth combined with oxygen and caesium, the ratio of the weight of silver to the weight of bismuth in said alloy being between 50:50 and 98:2.

6. A photosensitive electrode comprising a support, a film on a surface of said support including an alloy of silver and bismuth combined with oxygen, and caesium, the ratio of the weight of silver to the weight of bismuth in said alloy being between 80:20 and 98:2.

7. A photosensitive electrode comprising a support, a film on a surface of said support including an alloy of silver and bismuth combined with oxygen and caesium, the ratio of the weight of silver to the weight of bismuth in said alloy being 90:10.

8. A photosensitive electrode comprising a support, a film on a surface of said support including an alloy of silver and bismuth combined with oxygen and caesium, the ratio of the weight of silver to the weight of bismuth in said alloy being 95:5.

9. The method of making a photosensitive electrode, said method comprising the steps of, evaporating upon a support having a normal transparency a layer of silver-bismuth alloy until the light transmission through said support is reduced to approximately 38 per cent of normal transparency, oxidizing said silver-bismuth alloy layer until light transmission through said support is 50% of normal transparency, sensitizing

said oxidized silver-bismuth alloy surface by depositing caesium vapor upon said alloy layer.

10. A photosensitive electrode comprising a support, a film on one surface of said support including an alloy of silver and bismuth combined with oxygen and caesium, the ratio of the weight of silver to the weight of bismuth in said alloy being between the values of 85:15 and 95:5.

11. A photosensitive electrode comprising a support, a film on one surface of said support including an alloy of silver and bismuth combined with oxygen and caesium, the ratio of the weight of silver to the weight of bismuth in said alloy being 92.2:7.5.

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