United States Patent [19]

Sommer

[11] **3,884,539**

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[54] **METHOD OF MAKING A MULTIALKALI ELECTRON EMISSIVE LAYER**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 314,001, Dec. 11, 1972, abandoned.

[52] **U.S. Cl.** **316/6;** 117/215; 117/219; 316/3; 316/5

[51] **Int. Cl.** **H01j 9/38**

[58] **Field of Search** 316/3, 5, 6, 8, 10, 12, 316/17, 18, 19, 27; 117/215, 219, 223, 224, 211; 313/103

[56] **References Cited**

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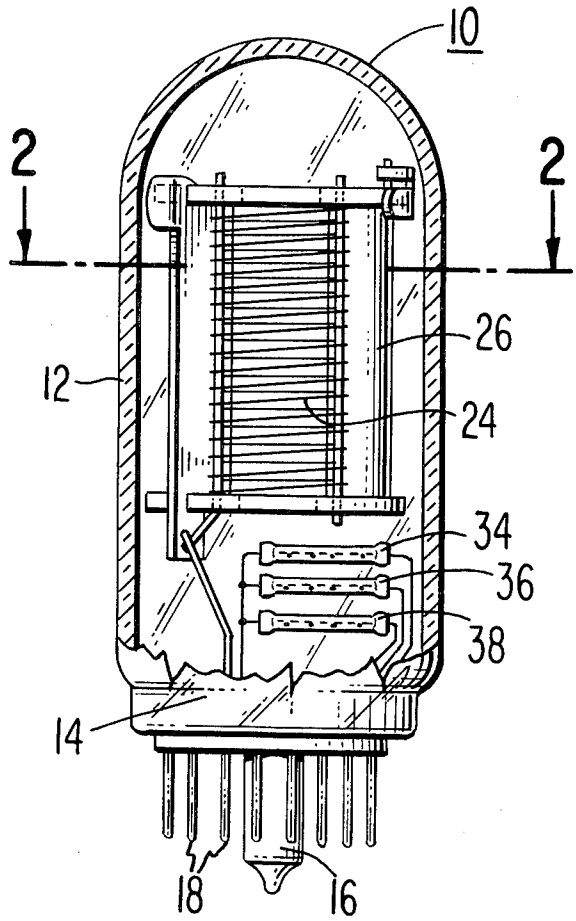
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[57] **ABSTRACT**

An S-20 response multialkali photocathode is produced by exposing a layer of antimony to activating vapors of potassium, sodium, and cesium. In one method the antimony layer is exposed to cesium at a temperature of about 240°C. prior to exposure to potassium or sodium, and the exposing to cesium is terminated before the photosensitivity reaches a peak. In another method, the antimony layer is exposed to cesium at a temperature of about 240°C. subsequent to exposure to potassium and sodium, and the exposing to cesium is terminated when the photosensitivity reaches a peak.

11 Claims, 2 Drawing Figures



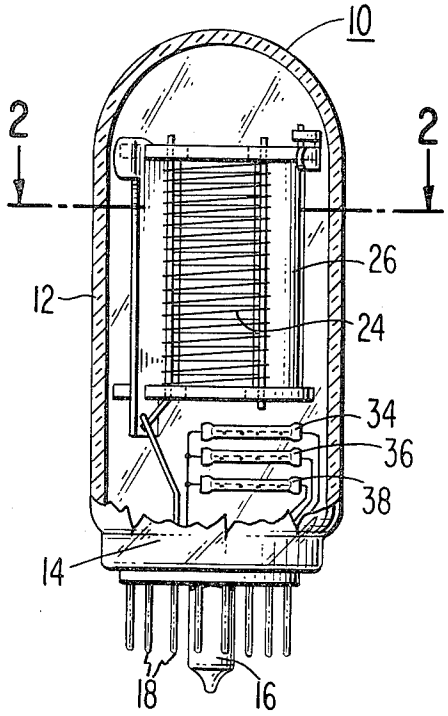


Fig. 1.

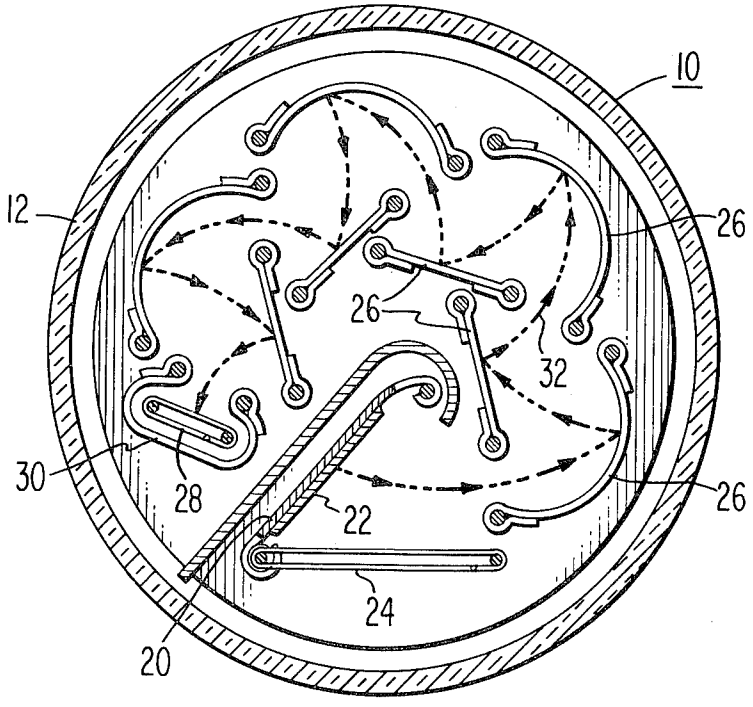


Fig. 2.

METHOD OF MAKING A MULTIALKALI ELECTRON EMISSIVE LAYER

The application is a continuation-in-part of application Ser. No. 314,001, filed Dec. 11, 1972, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to the processing of electron-emissive, or cathode layers comprising a layer of antimony activated with several alkali metals.

Electron-emissive layers are used, for example, as photocathodes or secondary electron-emitting layers in phototubes, image tubes, camera tubes and various other devices. One type of photocathode comprises antimony combined with potassium, sodium, and cesium. Such a photocathode is generally referred to as a "multialkali" or an "S-20" photocathode and has a characteristic spectral response known as an S-20 response. Relatively high efficiency S-20 photocathodes are made by a rather complex activation process including a number of evaporations of antimony on a predeposited layer of antimony during activation and exposure of the cathode at elevated temperatures to potassium, sodium, and cesium vapor between the evaporations. The exposures to potassium and to sodium are at temperatures on the order of 200°C. (Celsius), while the exposures to cesium are at temperatures on the order of 160°C. Such processes are described, for instance in U.S. Pat. No. 3,658,400 issued to Helvy on Apr. 25, 1972.

In some tubes, however, while it is desirable to have an S-20 photocathode, the configuration of the tube interior does not permit evaporation of a uniform layer of antimony inside the tube during activation of the cathode. For example, in certain photomultipliers and proximity focussed image tubes, an antimony evaporation source cannot be located sufficiently distant from the photocathode to deposit a uniform layer of antimony inside the tube during processing, either because the tube itself is not large enough, or because an electrode blocks the source. In these tubes, all the antimony must be pre-deposited on the photocathode substrate prior to tube assembly. Activation of the predeposited antimony layer according to prior art practices by exposure to potassium, sodium, and cesium,

and at the elevated temperatures generally used in activation of multiple antimony layer photocathodes yields a photocathode of unacceptably low sensitivity.

SUMMARY OF THE INVENTION

In the novel process an antimony layer is activated with a plurality of alkali metals including cesium wherein exposure of the antimony layer to activating vapor of cesium is at a temperature exceeding about 200°C. Specifically, the activation of an antimony layer comprises exposing the layer to cesium vapor at a temperature exceeding 200°C. either prior to or subsequent to exposing it to potassium and sodium vapors. If the exposure to cesium is accomplished before exposing the layer to potassium and sodium, the exposure to cesium is terminated before the photosensitivity reaches a peak.

With the novel process, the photosensitivity of the single antimony layer type of multialkali photocathode is greatly increased, thus making it commercially feasible to use S-20 response multialkali photocathodes in

devices in which the geometry does not permit evaporations of antimony during activation processing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a break-away, side view of a photomultiplier utilizing a photocathode made by the novel process.

FIG. 2 is a sectional view of the tube of FIG. 1 taken at line 2—2 of FIG. 1.

PREFERRED EMBODIMENT

In a preferred embodiment of the invention, the photomultiplier tube **10**, shown in FIGS. 1 and 2, is processed by the novel method.

Referring now to FIG. 1, the tube **10** has a glass envelope **12** with a stem portion **14**. The stem portion **14** includes a length of exhaust tubulation **16** and a number of embedded metal pins **18** for making electrical contact to the interior of the tube **10**.

Mounted inside the tube **10** is an electrode assembly shown in more detail in FIG. 2. The assembly includes a metal photocathode substrate **20** having an evaporated antimony photocathode layer **22** about 10-100nm (nanometers) thick on one face. Angularly disposed from the substrate is a mesh electrode **24**, which is followed, proceeding counterclockwise about the tube axis, by a series of **8** dynodes **26** and an anode **28** with an anode shield **30**. The general direction of travel of electrons emitted from the photocathode **22** is indicated by the dashed directional lines **32**. Between the electrode assembly and the stem **14** are a potassium channel **34**, a sodium channel **36** and a cesium channel **38** which can be electrically-resistance-heated for releasing their respective alkali metal vapors into the interior of the tube **10**.

As a preliminary step to activation of the photocathode layer **22**, an oven is placed around the tube **10** and the tube **10** is baked-out for several hours at a temperature of about 300°C. to eliminate contaminants from the interior. During the entire processing, the interior of the tube **10** is continuously evacuated through the exhaust tubulation **16**. After the tube **10** is baked out, the activation of the photocathode layer **22** may proceed as follows, with the photosensitivity of the photocathode **22** being monitored during processing, generally as described, for example in U.S. Pat. No. 2,676,282 issued Apr. 20, 1954 to J. J. Polkosky.

EXAMPLE 1

1. The temperature of the tube **10** is lowered from the bake-out temperature to about 240°C., and the cesium channel **38** heated so that a small amount of cesium vapor is released into the interior of the tube **10** until the photosensitivity reaches a value of approximately 0.1 microampere per lumen. Vaporization heating of the cesium channel is then terminated.

2. Next, the tube **10** is maintained at about 240°C. and the potassium channel **34** heated to release potassium vapor into the tube **10** until the photosensitivity reaches a peak value, generally somewhat below 10 microamperes per lumen. Vaporization heating of the potassium channel is then terminated.

3. With the tube **10** still maintained at about 240°C., the sodium channel **36** is now heated to release sodium vapor until another peak photosensitivity is reached. The vaporization heating of the sodium channel is then terminated, and the tube **10** is cooled to room temperature and the exhaust tubulation **16** sealed off.

EXAMPLE 2

1. The temperature of the tube **10** is lowered from the bake-out temperature to a temperature which exceeds about 160°C. as, for example, about 240°C. and the potassium channel heated to release potassium vapor into the tube **10** until the photosensitivity reaches a peak value. Vaporization of the potassium channel is then terminated.

2. Next, the tube is maintained or heated to a temperature above 220°C. as, for example, about 240°C. and the sodium channel **36** is heated to release sodium vapor until another peak photosensitivity is reached. The vaporization heating of the sodium channel is then terminated.

3. With the tube **10** heated to or maintained at a temperature about 240°C. the cesium channel **38** is heated so that cesium vapor is released into the interior of the tube **10** until photosensitivity reaches a peak value. The vaporization heating of the cesium channel is terminated and the tube **10** is cooled to room temperature, and the exhaust tubulation **16** sealed off.

GENERAL CONSIDERATIONS

In the prior art methods of activating antimony with sodium, potassium, and cesium, the cathode is maintained at a temperature on the order of only about 160°C. during activation with cesium vapor and the exposure is continued until the photosensitivity of the cathode is at or past a peak.

In the novel process, on the other hand, it is critical that the temperature of the cathode layer during the exposure to the cesium vapor be above about 200°C., which is higher than temperatures generally specified for the cesium in prior activation methods. Also, with the novel process, during exposure to each of cesium, potassium, and sodium a uniform temperature may be maintained without modification at between about 220°C. and about 240°C.

Regarding Example **1**, it is important that the amount of cesium generated not be excessive. It is preferred that the cesium be generated until the photosensitivity of the cathode reaches a value on the order of only 1/10 microampere per lumen, rather than to peak sensitivity, which would occur at a value of about 20 microamperes per lumen. While this particular value of 1/10 microampere per lumen may not be highly critical, it has been found, for instance, that if cesium is released until the photosensitivity is higher than about one-half microampere per lumen, the resulting photocathode is substantially inferior to one in which the cesium is released only until a value of about 1/10 microampere per lumen.

The method of Example 1 has been found to produce electron emissive layers, generally superior to those obtained by prior art methods of activating an antimony layer, in sequence, with the vapors of cesium, potassium, and sodium without additional evaporations of antimony.

Regarding Example 2, it has been found that the long wavelength response of such photocathodes, produced with the novel method, is considerably extended without additional antimony evaporation during activation.

I believe that the superior results obtained by the aforementioned methods results from the activation of the antimony layer with a plurality of vapors of alkali metals; such as for example, potassium, sodium and cesium vapors; wherein, a cesium activation is accomplished at very high temperature exceeding about 200°C. and preferably about 240°C.

While the process has been described for making a photocathode, the product of the process is an electron-emissive layer generally, whether the emission is primary or secondary.

I claim:

1. A method of activating a multialkali electron-emissive cathode layer, of the type wherein a layer of antimony is exposed at elevated temperature, within an evacuated body, to vapors of a plurality of alkali metals including cesium, to form an electron-emissive compound, wherein the improvement comprises:

exposing the cathode layer to cesium vapor to achieve a photosensitivity exceeding approximately 0.1 microampere per lumen while maintaining the cathode at a temperature above 200°C.

2. The method defined in claim **1**, wherein the antimony layer is activated by vapors of sodium, potassium, and cesium.

3. The method defined in claim **2**, additionally comprising the steps of:

exposing the cathode layer to cesium vapor prior to exposing it to potassium and sodium vapors, and

terminating said exposing to cesium before the photosensitivity of the cathode reaches a peak.

4. The method defined in claim **3**, wherein said terminating is before the photosensitivity of the cathode reaches about one-half microampere per lumen.

5. The method defined in claim **4**, wherein the cathode is at a temperature above 200°C. during the exposing to sodium and potassium vapors.

6. The method defined in claim **2**, comprising:

exposing the cathode layer to cesium vapor until the photosensitivity of the exposed cathode layer is about one-tenth microampere per lumen, while maintaining the temperature of the cathode layer at between 220°C. and about 240°C.; then

exposing the cathode layer to potassium vapor until the photosensitivity of the exposed cathode layer reaches a peak, while maintaining the temperature of the cathode layer at between about 220°C. and about 240°C.; then

exposing the cathode layer to sodium vapor until the photosensitivity of the exposed cathode layer reaches a peak, while maintaining the temperature of the cathode layer at between about 220°C. and about 240°C.

7. The method defined in claim **2**, additionally comprising the step of:

exposing the cathode layer, in sequence, with potassium, sodium, and cesium vapors.

8. The method defined in claim **7**, additionally comprising the step of:

terminating said exposing to each of the vapors of potassium, sodium, and cesium vapor when the photosensitivity of the cathode reaches a peak.

9. The method defined in claim **8**, wherein said cathode is maintained at a temperature of between about 220°C. and about 240°C. during said activation of said cathode with each of the vapors of sodium, and cesium.

10. The method defined in claim **9**, wherein said cathode is maintained at a temperature exceeding about 160°C. during said activation with potassium vapor.

11. The method defined in claim **2**, comprising:

exposing the cathode layer to potassium vapor until the photosensitivity of the exposed cathode layer reaches a peak, while maintaining the temperature of the cathode layer within the range of about 160°C. and about 240°C.

exposing the cathode layer, next, to sodium vapor until the photosensitivity of the exposed cathode reaches a peak, while maintaining the temperature of the cathode layer within the range of about 220°C. and about 240°C.

exposing the cathode, next, to cesium vapor until the photosensitivity of the exposed cathode reaches a peak, while maintaining the temperature of the cathode layer within the range of about 200°C. and about 240°C.

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