United States Patent [19]

Schade

[11] **3,906,277**

[45] **Sept. 16, 1975**

[54] **ELECTRON TUBE HAVING A SEMICONDUCTOR COATED METAL ANODE ELECTRODE TO PREVENT ELECTRON BOMBARDMENT STIMULATED DESORPTION OF CONTAMINANTS THEREFROM**

[75] Inventor: **Horst Ernst Paul Schade,** Mercer, N.J.

[73] Assignee: **RCA Corporation,** New York, N.Y.

[22] Filed: **May 5, 1972**

[21] Appl. No.: **250,804**

[52] **U.S. Cl.** **313/365;** 313/102

[51] **Int. Cl.²** **H01J 31/28;** H01J 31/26

[58] **Field of Search** ..... 313/65 R

[56] **References Cited**

UNITED STATES PATENTS

3,184,636	5/1965	Dore et al.	315/94
3,213,308	10/1965	Feibelman	313/65 R
3,478,213	11/1969	Simon et al.	313/103 X
3,614,499	10/1971	Deits et al.	313/65 T

FOREIGN PATENTS OR APPLICATIONS

672,205	5/1952	United Kingdom	313/65 T

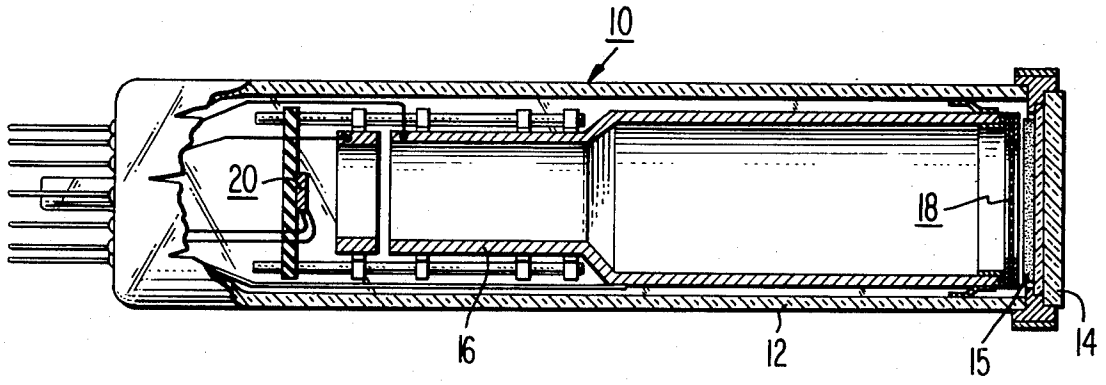
Primary Examiner—Robert Segal

Attorney, Agent, or Firm—G. H. Bruestle; D. S. Cohen

[57] **ABSTRACT**

An electron emissive tube of the type having therein a cesiated cathode, and also having a metal anode electrode. The improvement comprises a thin, clean, nonporous coating of semiconductor material on the surface of the electrode. The coating prevents degradation of the cathode by inhibiting the release of contaminants from the electrode by electron-bombardment-stimulated desorption.

5 Claims, 5 Drawing Figures



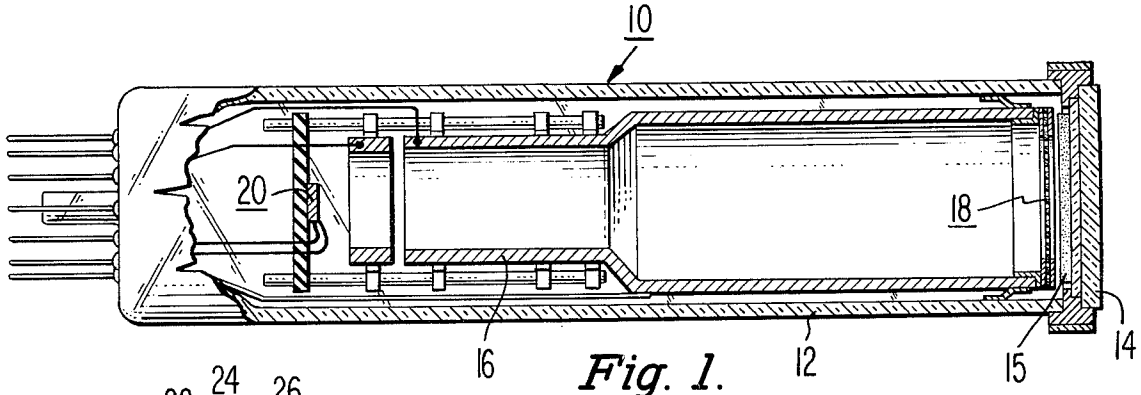


Fig. 1.

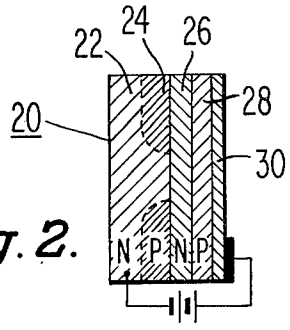


Fig. 2.

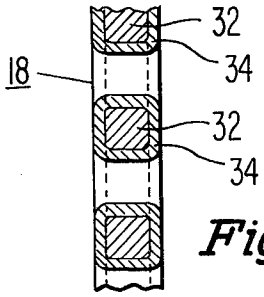


Fig. 3.

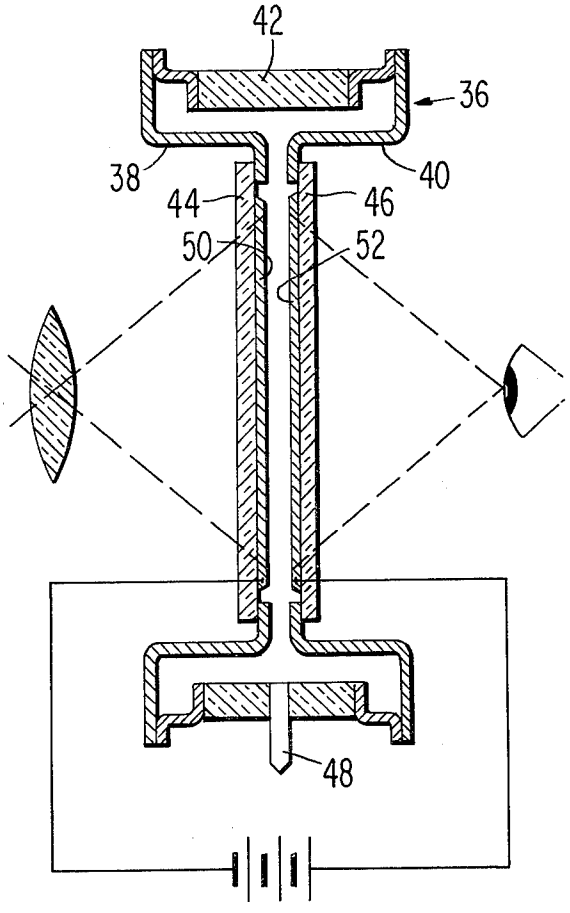


Fig. 4.

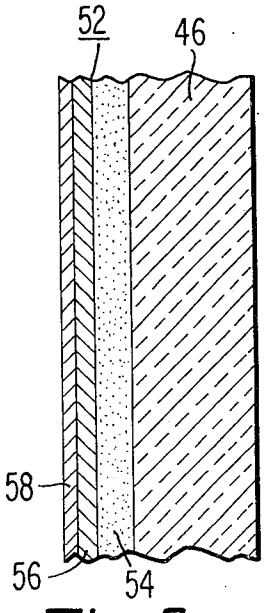


Fig. 5.

ELECTRON TUBE HAVING A SEMICONDUCTOR COATED METAL ANODE ELECTRODE TO PREVENT ELECTRON BOMBARDMENT STIMULATED DESORPTION OF CONTAMINANTS THEREFROM

The invention disclosed herein was made in the course of, or under, a contract or subcontract thereunder with the Department of the Army.

BACKGROUND OF THE INVENTION

The present invention relates to electron tubes comprising a metal anode electrode bombarded by electrons.

In certain electron tubes it is essential to the operating lifetime of the tube that the residual pressure be minimized. Such is the case for electron emissive tubes having a non-thermionic cesiated cathode–that is, an unheated cathode such as a "cold" cathode, a photocathode, or a secondary emitting cathode which is cesiated by application of a work-function-reducing layer to the emitting surface. The work-function-reducing layer may be either cesium alone, or cesium together with another material, such as oxygen or fluorine.

Such non-thermionic cesiated cathodes have characteristics which are desirable for electron tube cathodes. They are already widely used as photocathodes in image intensifier tubes and phototubes and as secondary emission cathodes in phototubes because of their high efficiency. Such cathodes are particularly suited in some respects as electron gun cathodes for television camera tubes and kinescopes. Electrons emitted therefrom have a relatively narrow velocity distribution, thereby allowing for better controlled focus and deflection of the electron beam. Also, as no heater is required to operate the cathode, less power is needed for operation of the tube.

Non-thermionic cesium activated cathodes, however, are particularly susceptible to degradation by contaminants released from nearby electron bombarded metal anode electrodes. Such contaminants as are normally adsorbed on the metal electrodes are released therefrom by electron bombardment stimulated desorption. Some of the released contaminants eventually impact on the emissive surface of the cathode and degrade the delicate nature of the work function reducing layer. The amount of released contaminants can be minimized by extensive cleaning of the metal anodes and other internal surfaces of the tube and, in addition, by maintaining the residual pressure of the tube as low as possible. Such measures, however, greatly add to the expense of manufacture of tubes and are for many tubes presently not commercially feasible to the extent necessary to protect the cathode.

SUMMARY OF THE INVENTION

The novel electron tube comprises a coating of semiconductor material on a metal surface bombarded by electrons. The coating may be applied to the surfaces of grids, grilles, anodes and other conductive metal structures in the tube.

The coating inhibits the desorption of contaminants from the electrode when bombarded with electrons, minimizing the residual pressure in the tube and thus increases the lifetime of the tube. The coating is effective to inhibit desorption from surfaces that are bombarded with electrons having energies of at least 20 electron volts. It may be used on surfaces which are bombarded continuously, periodically, or intermittently with electron beams or broad area exposure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cutaway side sectional view of a vidicon camera tube in accordance with one embodiment of the invention.

FIG. **2** is a greatly exaggerated sectional view of the electron gun cathode of the vidicon of FIG. **1.**

FIG. **3** is a greatly exaggerated view of a fragment of the mesh electrode of the vidicon of FIG. **1.**

FIG. **4** is a side sectional view of a proximity focussed image intensifier tube in accordance with another embodiment of the invention.

FIG. **5** is a greatly exaggerated sectional view of a fragment of the output screen electrode of the image tube of FIG. **4.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

EXAMPLE 1

One embodiment of the invention is the vidicon television camera tube **10** shown in FIG. **1** of the drawings. The tube **10** comprises a glass envelope **12** sealed at one end by a glass faceplate **14.** On the inside surface of the faceplate **14** is a photoconductive target **15.** Disposed inside the major portion of the envelope is an electron gun assembly **16** for generating an electron beam which is focussed and deflected across the target **15** by exterior magnetic coils, not shown. At the end of the gun assembly **16** and spaced closely from the target **15** is a metal mesh anode electrode **18** for applying a voltage which decelerates beam electrons before they strike the target **15.** At the end of the gun assembly **16** remote from the target **15** is a cathode **20.**

The cathode **20,** shown greatly exaggerated in FIG. **2,** is a forward-biased junction type cold cathode having a negative effective electron affinity surface. It comprises a substrate **22** of N type gallium arsenide (GaAs). An N type annular confining region **24** is formed in one surface of the GaAs by diffusion of zinc into the substrate **22.** An N type layer **26** of aluminum-gallium-arsenide alloy about 6μm (micrometers) thick is grown over the entire surface. A P type emitting layer **28** of germanium-doped GaAs is grown on the alloy layer **26** to a thickness of 4μm. On the emitting layer **28** is a thin work-function-reducing layer **30** of cesium and oxygen. In operation of the cathode, the substrate **22** is biased about two volts negative with respect to the emitting layer **28.**

A portion of the metal mesh anode electrode **18** spaced from the target **15** is shown in FIG. **3** greatly exaggerated. The electrode **18** is an electroformed mesh **32** of nickel coated with desorption-inhibiting coating **34** of GaAs about 200 nm (nanometers) thick. The coating **34** inhibits desorption of gases from the mesh electrode **18** when the scanning electron beam from the gun assembly **16** scans the target **15** through it.

The coating **34** is applied to the mesh electrode **18** before its incorporation into the tube **10.** First the mesh **32** is cleaned by firing in hydrogen at a temperature of about 1000°C for about 10 minutes. Then, the gallium arsenide layer **34** is vapor-deposited on the mesh **32** by flash evaporation in a separate vacuum chamber. A tantalum crucible near the mesh **30** is heated to a temperature of about 1200°C (centigrade). Then gallium

arsenide powder is introduced into the crucible until the proper thickness of the coating **34** is obtained. The thickness may be monitored by timing the evaporation for a predetermined rate of addition of gallium arsenide powder to the crucible. The processing of the tube **10** after installation of the various internal components is generally in accordance with presently used procedures for vidicon camera tubes. Such processing includes cleaning of all the exposed interior surfaces by heating them to a sufficiently high temperature to drive off most of the absorbed and adsorbed gases, and to remove these gases from the tube. This may be accomplished by various techniques of baking the tube while continuously evacuating it, and by heating particular metal parts to higher than the baking temperature by resistance heating or radio frequency induced heating.

EXAMPLE 2

Another embodiment of the invention is a proximity-focussed image tube **36** shown in FIG. **4.** The tube **36** comprises an envelope assembly which has a pair of opposing supporting flanges **38** and **40** welded to a short glass cylinder **42** to form a double rim. One flange **38** supports an input faceplate **44,** and the other flange **40** an output faceplate **46.** The faceplates **44** and **46** are hermetically sealed to the flanges **38, 40** so that the entire envelope assembly can be evacuated through a short piece of exhaust tubulation **48** and sealed. The faceplates **44** and **46** are closely spaced inside the envelope at a distance of about 3 millimeters to minimize defocussing effects. On the inside surface of the input faceplate **44** is a cesium activated photocathode **50.** On the inside surface of the output faceplate **46** is a phosphor output screen **52.**

The input faceplate **44** is a single crystalline disc of alpha-type aluminum oxide, also known as synthetic sapphire, about one inch in diameter and 25 mils thick. The faces of the faceplate **44** are cut so that they lie in the Miller Index crystallographic plane designated as $(1\bar{1}02)$ and are optically polished. The output faceplate **46** is optical glass having dimensions on the order of the dimensions of the input faceplate **44.**

The photocathode **50** is about **18** mm in diameter and comprises three epitaxial layers coated directly on the inside surface of the input faceplate **44.** Beginning from the input faceplate **44,** there is first a layer of silicon about 200 nm thick. On the silicon is a second layer, of gallium phosphide, about 5 μm (micrometers) thick. On the gallium phosphide layer is a third layer, of gallium arsenide, about 1 μm thick. The surface of gallium arsenide is activated by addition of a layer of cesium and oxygen to reduce the work function.

Typical procedures for assembly and processing of photocathodes and proximity-focussed image tubes are described, for instance, in U.S. Pat. No. 2,975,015 issued 14 Mar. 1961 to D. W. Davis (cl. 316–19) respectively.

The output screen **52** of the image tube **36,** a portion of which is shown in greater detail in FIG. **5,** is a layer of phosphor **54** having on its surface a thin layer **56** of aluminum metal which acts together with the underlying phosphor layer **54** as anode electrode for photoemitted electrons from the photocathode **50.** On the aluminum layer **56** is a desorption inhibiting coating **58** of gallium arsenide about 100 nm thick. The coating may be applied by flash evaporation generally as described in Example 1 above.

The coating **58** of gallium arsenide on the aluminum metal layer **56** prevents electron stimulated desorption of contaminants from the aluminum layer **56,** and thus preserves the lifetime of the photocathode **50,** while at the same time having no significant effect on the desired anode electrode function of the output screen **52.**

In operation of the tube **36,** a light image is focussed through the input faceplate **44** to the photocathode structure **50,** which is biased at several thousand volts negative with respect to the phosphor output screen **52.** In response to the incident light, electrons emitted by the photocathode **50** travel a short distance to the phosphor output screen **52,** whereupon a substantial portion of them pass through the gallium arsenide layer **58** and the aluminum layer **56** to the phosphor **54** and result in generation of output light, which is emitted through the output faceplate **46.**

GENERAL CONSIDERATIONS

The present invention relates to electron tubes having a metal electrode which is bombarded by electrons or other particles having average energies on the order of at least 20 electron volts and for which the tube lifetime is dependent on minimizing of the residual pressure of certain gases desorbed from the metal electrode. Energies of less than about 20 electron volts do not result in substantial desorption. Such tubes may include, for example, kinescopes, camera tubes, image tubes, and photomultipliers. The invention is especially useful for tubes which comprise cesium activated unheated cathode of the type having a negative effective electron affinity cathode, such as is described for instance in U.S. Pat. No. 3,478,213 issued to R. E. Simon et al. 11 Nov. 1969.

Electron bombardment stimulated desorption is especially pronounced at surfaces which are actively bombarded only periodically, and which between bombardments are passive for a sufficient time to adsorb considerable amounts of residual gases. When the surface is next bombarded, the adsorbed gases are released suddenly into the tube interior. After a time, a major portion of the released gases are adsorbed on other passive surfaces of the tube interior, such as the glass walls or the cathode, until a dynamic equilibrium is reached. In this way, residual gases are repeatedly made available at relatively high concentrations for adsorption to the cathode surface.

The amount of residual gas adsorbed to a surface during a passive period depends largely on the sticking probability for the gas particles with respect to that surface. Clean metallic surfaces generally adsorb gases much more readily than do clean semiconductor surfaces. Appropriately, the sticking probability for a common residual gas, such as oxygen for example, on a clean metal surface is on the order of one tenth, whereas for a clean semiconductor the probability is on the order of one thousandth. Therefore, when, as in the Examples 1 and 2 above, the metal anode electrode of a tube is coated with a non-porous coating of semiconductor, the degree of periodic adsorption and desorption of gases is greatly inhibited by a factor of about one hundred, so that the lifetime of the cathode surface is increased accordingly.

The desorption-inhibiting coating may be of most any semiconductor, since most semiconductors exhibit low sticking probabilities for gases. Sticking probabilities for a number of semiconductors are given, for instance,

in M. Green, "Oxygen Sticking Coefficients on Clean Semiconductor Surfaces" in SURFACE SCIENCE 3 (1965) 419–420. Whereas a number of compound semiconductors have lower sticking probabilities than do the common semiconductors silicon and germanium, the latter are perhaps more desirable from a practical standpoint, since it is generally easier to evaporate an elemental semiconductor than a compound one. The inhibiting coating may, however, be applied in any convenient manner which provides a non-porous coating, for example by vapor phase deposition from a carrier gas.

While it is desirable that the entire bombarded surface of the electrode be coated with semiconductor, coating any portion which is bombarded by electrons will lessen the amount of adsorption and desorption of gases thereon, and thereby decrease to some degree degradation of the cathode surface.

The semiconductor coating should be at least thick enough to be non-porous–that is, essentially impervious to residual gases in the tube. The actual minimum thickness needed to form a non-porous coating depends to some extent upon the method used to apply it upon the particular semiconductor in question. For flash evaporated gallium arsenide, a minimum thickness of about 100 nm is needed to form a non-porous coating. The coating should be clean, or essentially free of adsorbed gases. This may be achieved by heating the coating under vacuum or by not exposing the coating to undesirable gases after its vapor deposition.

The semiconductor coating should, in general, be kept thin, so that it has a minimal effect upon the conductivity of the collector. For the case of an image tube, as in Example 2 above, in which the electrons must pass through the semiconductor coating and the underlying metal to impinge on the phosphor, it is especially important that the semiconductor coating be thin, so that the electrons will readily pass through it.

I claim:

1. An improved electron tube of the type having:

a. an evacuated envelope;

b. an electron emitting cathode mounted within said envelope, said cathode having a cesiated layer thereon;

c. at least one electrode in said envelope for controlling electron flow from said cathode;

d. means for energizing electrons emitted from said cathode to an energy of at least 20 electron volts; and

e. at least one metal surface within said envelope in the path of said emitted electrons;

wherein the improvement comprises a clean, nonporous coating of semiconductor material on said metal surface to inhibit desorption of gases from said surface when said surface is struck by electrons.

2. The tube defined in claim **1** wherein

a. said cathode is part of an electron gun which focuses the electrons from said cathode, and

b. said metal surface is a metal anode for receiving the electrons from said electron gun.

3. The tube defined in claim **2** wherein said cathode is a cold cathode.

4. The tube defined in claim **3** wherein said anode comprises a perforated metal member spaced from said gun and bombarded by electrons from said gun.

5. The tube defined in claim **1** wherein said cathode is a photocathode, and said metal surface is a metal coating on a phosphor screen spaced from said photocathode.

* * * * *