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NON-PHOTOEMISSIVE GRID FOR A PHOTOTUBE
AND PROCESS FOR MAKING SAME
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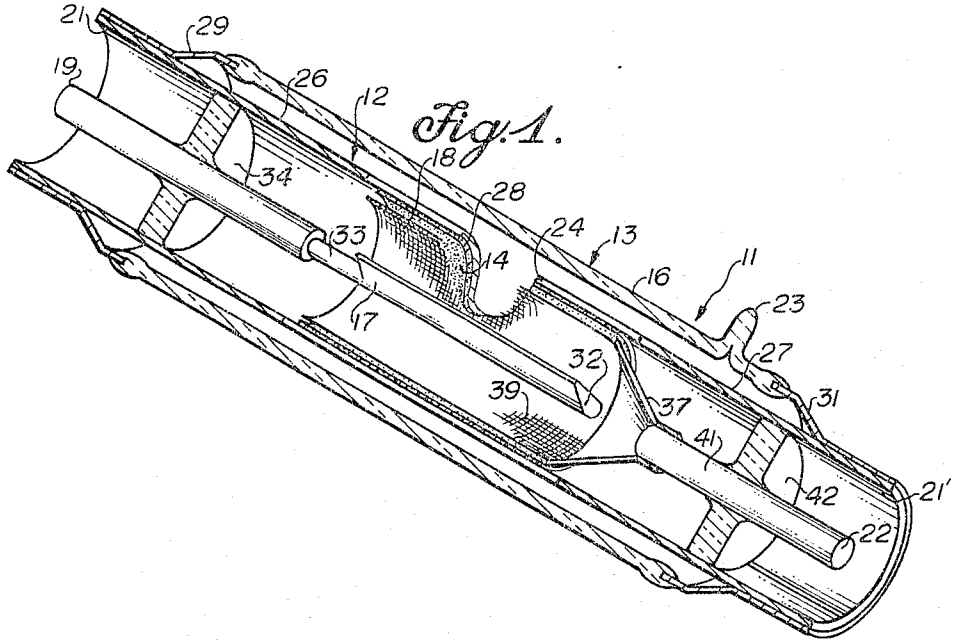
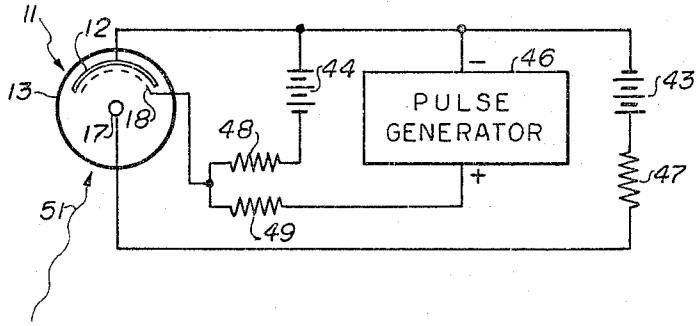



Fig. 1.

Fig. 2.




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# NON-PHOTOEMISSIVE GRID FOR A PHOTOTUBE AND PROCESS FOR MAKING SAME

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The present invention relates to a process for treating electron tube elements and to tubes employing the treated elements therein. More specifically, this invention relates to a process for rendering a surface of tube elements non-photoemissive and to a grid-controlled phototube having a non-photoemissive control grid.

In the past, the presence of "dark currents" have frustrated attempts to make grid-controlled phototubes whose anode currents could be effectively cut off by biasing the control grid negative with respect to a photoemissive cathode. This "dark current," as the term is used herein, is that current which ordinarily flows to the anode in the presence of a bias between the control grid and photoemissive cathode of a magnitude which normally would be expected to inhibit photo-induced current flow from the cathode to the anode. It has been found that the "dark current" originates from the control grid and such current exists because those processes commonly used to activate the photoemissive cathode of a phototube are of such a nature that the control grid as well as the photocathode is rendered photoemissive. In a typical process for activating a photoemissive cathode, a film of appropriate photoemissive material, such as antimony, is deposited on a metal substrate which provides structural support for the photoemissive cathode. This substrate along with an anode and a grid is mounted in a glass envelope prior to activation of the cathode to form the phototube. The glass envelope is then evacuated and an evaporated photoactivating material, such as cesium, is introduced into the tube. This cesium or other similar material migrates to the substrate and reacts with the antimony evaporated thereon thereby forming a photoemissive cathode having a low work function surface. During this process the cesium must diffuse through the mesh openings in the grid in order to reach the cathode surface. Consequently, a considerable amount of cesium is deposited on the grid thereby rendering that grid also photoemissive. Although this cesiated grid is not nearly so photosensitive as the cathode, nevertheless, its work function is reduced to a point where the above-mentioned "dark currents" originating therefrom substantially degrade tube performance. Although an electrostatic field established by a negative grid-cathode bias voltage may be sufficient to repel substantially all photoelectrons emitted from the cathode, since the grid is photoemissive, it is capable of producing photoelectrons which create an anode current.

The present invention provides a unique process of treating the grid electrode of a grid-controlled phototube, or any other material structure, to render the structure non-photoemissive. The term photoemissive as used herein will refer to photosensitivities equal to or greater than six microamperes per lumen per square inch of emission surface. The term non-photoemissive will relate to photosensitivities which are substantially less than the above noted six microampere level. In the process of the invention, the surface of the structure to be rendered non-photoemissive is initially coated with a material which when exposed to a selected photoactivating agent will interact therewith to form on the surface a coating having a work function whose magnitude is greater than or which is not reduced more than one order of magnitude less than that of the unprocessed structure material. The maintenance of a high work function on the surface of the material renders the surface substantially non-photoemissive.



A material which will so interact will be termed hereinafter as a "photoemissive retardant." After applying the photoemissive retardant to the surface, the photoactivating agent is coated thereover whereby a reaction is believed to occur between the two coatings to create thereby a non-photoemissive surface.

Materials which will serve as appropriate photoemissive retardants depend upon the particular photoemissive activating agent being used. Photoemissive activating agents can be selected from numerous materials, such as, the alkali metals of cesium, sodium, potassium, rubidium, etc. Where cesium is employed as the activating agent, materials such as iron, tin, lead and chlorides of nickel are used as the photoemissive retardants.

By treating the grid electrode of a grid-controlled phototube in accordance with the process of the present invention, a grid-controlled phototube characterized by the substantial absence of the undesirable "dark current" is produced.

Accordingly, the primary object of the present invention is to provide a process in which a surface inadvertently exposed to a photoemissive activator is retained in a non-photoemissive state.

It is a more particular object of the present invention to provide a process for rendering a surface photoemissive while objects proximate the surface are retained in a non-photoemissive state.

It is a further object of the present invention to provide a grid-controlled phototube having a greatly decreased level of dark current.

It is a more particular object of the present invention to provide a grid-controlled phototube having substantially no "dark currents."

It is yet another object of the present invention to provide a grid-controlled phototriode tube whose grid electrode is non-photoemissive.

These and other objects of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings in which:

FIGURE 1 isometrically depicts a grid-controlled phototriode tube provided with a non-photoemissive grid in accordance with the invention; and

FIGURE 2 schematically depicts a phototriode tube and typical associated circuitry.

Referring to FIGURE 1, phototriode tube **11** typically includes a photoemissive cathode electrode **12** mounted within a hermetically sealed envelope **13**. To provide a light path through envelope **13** to the photoemissive surface **14** of cathode electrode **12**, envelope **13** includes a central portion **16** composed of light pervious material such as glass arranged in facing relationship with electrode **12**. An anode electrode **17** is rigidly secured in spaced, insulated relation to cathode electrode **12** substantially axially within envelope **13** to receive photoelectrons liberated from photoemissive surface **14** as a result of light impinging thereon. Towards effectively controlling the current flow from cathode electrode **12** to anode electrode **17**, a mesh screen grid electrode **18**, pervious to electron passage, is disposed coextensively between and insulated from anode electrode **17** and cathode electrode **12**. Grid electrode **18** is positioned proximate the photoemissive surface **14** of cathode electrode **12** to, in effect, electro-statically shield cathode electrode **12** from anode electrode **17**. The tube's anode cathode and grid electrodes, **17**, **12** and **18** respectively, are provided with conductive extensions **19**, **21**, and **22** which transpierce envelope **13** in hermetically sealed insulated relation thereto for connection to exterior circuitry.

In accordance with conventional construction practice, the cathode electrode **12** is treated to render its surface responsive to light impinging thereon, i.e., photoemissive. However, because of the particular manner in which the cathode activation process is conventionally carried out (as fully described in the literature, for example, Zworykin and Ramberg, "Photoelectricity," published by John Wiley and Sons, Inc., 1949), the treating process results in rendering the grid electrode **18** to be photoemissive. In such a conventional cathode activating process, the tube **11** is baked out at 275° C. until a pressure of about $1\times10^{-8}$ mm. Hg is attained. The tube **11** is then brought to about a 160° C. processing temperature and allowed to stabilize thereat. Cesium vapor, or other appropriate photoemissive activating material, is generated in a side-arm (not shown) and introduced into tube **11** through pump out tabulation **23** by differential heating. This cesium diffuses through grid electrode **18** to impinge on cathode electrode **12** and combine with antimony deposited on the surface of cathode electrode **13** which is to be exposed to light. The cesium and antimony react to form the photoemissive cathode surface **14** of cesium antimonide, this photoemissivity being the concomitant of the extremely low work function of the cesium-antimony combination. In the process of activating cathode electrode **12**, some of the diffusing activating material, i.e., cesium in this case, settles on grid **18** instead of passing through the grid to deposit on the surface of cathode electrode **12**. As noted previously, in the past such deposition of the cesium on the grid structure **18** rendered the grid photoemissive.

However, in the process of the present invention, the grid **18** is treated to provide a coating of certain select retardant agents thereon prior to activation whereby the subsequently deposited cesium forms a non-photoemissive surface on grid **18**. With alkali metal activators, effective retardant agents include iron, tin, lead and chlorides of nickel ($NiCl_2$). The preferred procedure for applying such materials is by means of a vacuum vapor deposition. However, iron has been found to be most effective as a retardant grid coating when cesium is employed to activate the cathode electrode of a grid-controlled phototube so as to substantially eliminate undesired photoemissivities of the grid **18**. It is thought that the iron interacts with the subsequently deposited cesium in some unexplained manner to raise the work function of the surface to eliminate the photoemissivity. While the metallic elements are generally applied by a vapor plating or vacuum vaporization process, it has been found that the nickel chloride may also be applied if a nickel grid is employed merely by dipping the grid into diluted hydrochloric acid. Evidently sufficient chloride is adsorbed or otherwise is retained by the nickel surface to be effective.

In the preferred embodiment described herein, the non-photoemissive zone of interaction product is formed by depositing cesium on at least a monomolecular layer of pure iron. However, a similar effect will be obtained by arranging for other photo-activating agents to deposit on a layer of appropriate photoemissive retardant and thereby render the surface non-photoemissive.

In the preferred process of rendering the grid electrode **18** of the grid-controlled phototube **11** non-photoemissive, oxide-free iron is vacuum deposited by well-known conventional techniques onto grid **18** to cover the surface thereof with at least a monomolecular thickness layer of iron. The electrodes, i.e., anode **17**, cathode **12** and iron coated grid **18**, are then assembled within envelope **13**, and the envelope **13** hermetically sealed and evacuated as in conventional practice. To prevent outgassing problems which could poison the photoemissive cathode during operation, iron coated grid **18** should be exposed to the atmosphere as little as possible during the fabrication of phototube **11**. To assure minimum exposure of the iron coated grid **18** to the atmosphere, both the coating process and assembly of phototube **11** can be completed within a single vacuum chamber thereby never exposing the iron coated grid electrode **18** to the atmosphere. The coating of iron can conceivably be applied to the grid surface, e.g., of nickel by any method which is suitable for obtaining an oxide free deposit. Possibly a grid formed of iron could be treated with reducing agents or by heating in a vacuum to yield a grid inherently capable of retarding photoemissivity. In any event, vapor deposition performed under high vacuum conditions in which a heated wire or pool of molten iron is used to produce the vapor, has been found eminently suitable. The other agents mentioned herein are deposited similarly. The surface of cathode electrode **12** is then activated to form the photoemissive cathode surface **14** in the manner noted supra.



The process of the present invention may be employed to fabricate any of the various grid-controlled phototubes, e.g., a grid-controlled electron multiplier tube or a grid-controlled photoelectronic image tube. However, the process is most important in the construction of a fast, high-current phototriode tube which is capable of being gated on in less than 3 nanoseconds, with the on-off current ratio being on the order of 10–3.

With particular reference to FIGURE 1, using the typical elements described above, the cathode **12** of a fast high-current phototriode tube is comprised of a semicylindrical tube **24** of conducting material, such as Kovar (a nickel-cobalt-iron alloy manufactured by Westinghouse Electric Corporation) having first and second cylindrical ends **26** and **27**. A semicylindrical sheet substrate **28** comprised of a metal such as nickel, chromel or alumel, is rigidly secured, e.g., by spotwelding, in nested relation to the inner surface of tube **24**. This substrate supports the photoemissive cathode surface **14** next to be described. In preferred practice antimony is evaporated to deposit on the inner surface of substrate **28** to a film thickness corresponding to approximately 58% light transmission. The cathode electrode **12** is completed by activating its surface with cesium thereby forming the photoemissive surface **14** of cathode **12** as described above.

Cathode electrode **12** is rigidly mounted within cylindrical glass envelope **16** having first and second supporting metal tapered tubular members **29** and **31** sealed respectively at each end and engaging the cylindrical ends **26**, **27** of tube **24**. Cathode electrode **12** is mounted within envelope **13** by hermetically inert gas arc-welding ends **26** and **27** to members **29** and **31** respectively.

Anode electrode **17** is provided with a "blade-shaped" configuration and is rigidly mounted within envelope **13** with a narrow edge **32** facing and spaced from the photoemissive surface **14** of cathode electrode **12**. Anode electrode **17** is secured in position by a conducting mounting post **33** extension thereof which penetrates an insulating seal support **34** which is rigidly mounted to the inner surface of cylindrical end **26** of tube **24**.

Grid electrode **18** is fabricated from a nickel mesh screen of 84% open transmission ratio. The screen is formed into a semicylindrical configuration and is fused to a conforming nickel frame **37**. At least, the inner surface **39** of semicylindrical screen grid **18** is covered by a first layer of oxide-free iron in accordance with the invention. The layer of iron is in turn covered by a layer of cesium which interacts therewith to form a non-photoemissive control grid **18**. Control grid **18** is disposed between anode electrode **17** and cathode electrode **12** proximate to and in spaced nested relation with photoemissive cathode surface **14**. For most efficient operation, the entire photoemissive cathode surface **14** is shadowed by screen grid **18** to thereby electrostatically shield cathode electrode **12** from anode electrode **17**. The control grid assembly **18** is rigidly held in position by a conducting post **41** extension secured to frame **37** and which hermetically penetrates an insulator seal **42** rigidly hermetically mounted to the inner surface of cylindrical end **27**

of tube 24. Insulator seals 34 and 42 further serve to hermetically seal envelope 13.

To provide the means of applying selective voltages to the tube's electrodes, each electrode, i.e., anode 17, cathode 12 and grid 18 are provided with conductive extensions 19, 21 and 22 respectively which hermetically transpierce to the exterior of envelope 13. Anode extension 19 is a conductive extension of post 33 which coaxially hermetically transpierces seal 34. Extension 22 of grid 18 is that portion of post 41 which coaxially hermetically transpierces seal 42. Cathode electrode 12 is provided with two conductive extensions, 21 and 21', which hermetically extend respectively through opposite ends of envelope 13 to the exterior thereof. Conductive extension 21 is formed by member 29 and the cylindrical extension 26 of cathode electrode 12. Conductive extension 21 coaxially surrounds anode extension 19 to form a coaxial connector. Similarly, conductive extension 21' is formed by member 31 the cylindrical extension 27 of cathode electrode 12. The conductive extension 21' coaxially surrounds grid extension 22 to form another coaxial connector. Hence, a phototriode tube is provided with coaxial input terminals to the grid-cathode portion of tube 11 and coaxial output terminals to the anode-cathode portion of tube 11.

FIGURE 2 shows tube 11 as connected in a conventional electronic circuit. In the figure, cathode 12 connects to the negative terminal of power source 43, to the positive terminal of power source 44, and to the positive terminal of pulse generator 46. The positive terminal of power source 43 connects through resistor 47 to anode 17. The negative terminal of power source 44 connects through resistor 48 to control grid 18 and the negative terminal of pulse generator 46 also connects to grid 18 through resistor 49.

In operation, light, depicted by arrow 51, penetrates through glass envelope 13 and impinges on grid 18 and cathode 12. The energy of the light is transferred to the electrons of such surfaces. Since the surface 14 of the cathode 12, as described above, has a low work function, those electrons whose energy is sufficiently increased by the light bombardment are able to overcome the surface energy potential barrier and escape into the evacuated region of the phototube. The negative potential imposed on grid 18 by power supply 44 repels these electrons and hence cuts off current to anode 17. When grid 18 is pulsed positive with respect to cathode 12 the photoemitted electrons are able to pass the grid and are accelerated to positively biased anode 17. These electrons flowing to anode 17 set up a current which passes through resistor 47. The number of electrons flowing are proportional to the intensity of the incident light 51. Hence, by an "Ohm's law" calculation, it is seen that the voltage appearing across resistor 47 is proportional to the intensity of the incident light.

With this circuit arrangement it is possible to observe an illuminated event over the time duration defined by the pulse of generator 46. As mentioned earlier, grid 18 was pretreated to provide a layer of vapor deposited iron such that the cesium deposited thereon interact with this iron to provide a high work function surface. With this high work function surface, the light impinging on the concave surface of grid 18 does not impart sufficient energy to the electrons within the grid to allow the electrons to overcome the surface barrier and escape into the evacuated region of the tube. Hence, there are none of the before mentioned "dark currents" in this tube.

An on-off current ratio is a convenient figure of merit to illustrate the effectiveness of the present invention. In the preferred embodiment described immediately above, use of the iron coated control grid 18 resulted in an on-off current ratio in excess of 1400:1. This is in sharp contrast with current ratios of less than 200:1 found in phototriodes not utilizing the novel iron coated grid 18. A comparative analysis of these two on-off ratios reveals a greater than seven to one reduction in "dark current" attributable to the use of the pretreated grid.

The use of a "blade-shaped" anode 17 having an elongated cross section serves to improve the response of the present phototube to those pulses imposed on control grid 18. There is a tendency for a substantial portion of the photoelectrons to miss the front narrow edge 32 of anode 17. Now, should this anode be comprised of a slender member, these electrons would spiral around the anode whereby they would gradually approach it. The duration of this spiralling represents a degradation in the response of the tube to those "on" pulses impressed on grid 24. By simply incorporating an elongated cross section feature to the anode, this spiralling effect is eliminated. Although the electrons may initially miss the front edge 32 of the anode 17, they immediately are intercepted by the extended portion of the anode 17, thus eliminating the spiralling transit time.

It may be worth noting that this elongated cross section anode feature and the coaxial feature of this phototriod are described in substantial detail in the inventor's copending application Ser. No. 237,777 filed, Nov. 14, 1962, entitled, "Ruggedized Photodiode Tube."

At this point it should be emphasized that the concept of pretreating a surface with a material that will react with a photoemissive material introduced into the tube so as to produce a non-photoemissive high work function surface is not limited in its application to the grid. The concept is applicable in any setting where the formation of photoemissive surfaces is desired to be prevented.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects and therefore the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. In a process for forming a photoemissive cathode of a grid-controlled phototriode tube without rendering the grid photoemissive, the steps comprising,

(a) directing a photoemissive retardant vapor onto a surface of a grid electrode defining mesh openings to form at least a monomolecular coating of photoemissive retardant on said surface,

(b) positioning said grid electrode proximate a cathode electrode of said phototriode tube with said coated surface of said grid electrode distal said cathode electrode, and

(c) directing a vaporized photoactivating material towards said cathode from a region on the side of said grid electrode distal said cathode whereby the coated surface of said grid electrode intercepts a portion of said vaporized photoactivating material directed towards said cathode, said photoemissive retardant deposited on said grid interacting with said intercepted photoactivating material to form a non-photoemissive zone of reaction products, said photoactivating material vapor passing through said mesh openings of said grid settling on the surface of said cathode proximate said grid to render said surface photoemissive.

2. In the process recited in claim 1 further defined by said grid and cathode electrodes being coated in an oxygen free environment, said photoemissive retardant vapor being iron, and said photoactivating vapor being cesium.

3. In a phototube including at least one photoemissive cathode electrode and at least one non-electron-emissive anode electrode positioned to receive photoelectrons emitted from the photoemissive surface of said cathode in response to light impinging thereon, the combination therewith comprising,

(a) a mesh grid disposed proximate the electron emitting surface of said cathode electrostatically between said cathode and anode electrodes, the surface of said grid facing said light that is to impinge upon said cathode coated with a non-photoemissive interaction product of a photoemissive retardant and a photoemissive activating agent.

**4.** A grid-controlled phototriode tube comprising,

(a) a hermetically sealed envelope,

(b) a photoemissively activated cathode electrode disposed within said envelope and having a surface responsive to light impinging thereon by the emission of electrons,

(c) a non-electron-emissive anode electrode positioned within said envelope insulated apart from said cathode to receive said electrons emitted by said cathode,

(d) a mesh grid electrode disposed proximate the surface responsive to light, the surface of said grid distal said cathode coated with a non-photoemissive interaction product of a photoemissive retardant and a photoemissive activating agent, and

(e) connector means connected to said anode, cathode and grid electrodes and exteriorly extending through said envelope in hermetic sealed relation thereto.

**5.** The phototriode tube recited in claim **4** further defined by said non-photoemissive reaction product formed by the reaction between a layer of cesium deposited on a layer of oxide-free iron.

**6.** A grid-controlled phototriode tube comprising,

(a) a hermetically sealed light-pervious envelope,

(b) a semicylindrical cathode disposed within said envelope and having its concave surface responsive to light impinging thereon by the emission of electrons,

(c) a blade-shaped anode positioned within said envelope with a narrow edge facing and having a common plane of symmetry with said semicylindrical cathode,



(d) a semicylindrical mesh grid electrode of conductive material disposed proximate to and in nested relation with said concave surface of said cathode, the surface of said grid electrode distal said cathode coated with a non-photoemissive interaction product formed by the reaction between a layer of cesium deposited on a layer of oxide-free iron,

(e) a first coaxial connector having inner and outer conductors, said inner and outer conductors connected to proximate ends of said grid and cathode electrodes respectively and hermetically transpiercing to the exterior of a first end of said envelope, and

(f) a second coaxial connector having inner and outer conductors, said inner and outer conductors connected to proximate ends of said anode and cathode electrodes respectively and hermetically transpiercing to the exterior said envelope through the end opposite said first end of said envelope.

**7.** The process recited in claim **1** further defined by said photoemissive retardant vapor selected from the vapors consisting of iron, lead and chloride of nickel vapors.


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