

[54] **PHOTODIODE CONTROLLED ELECTRON VELOCITY SELECTOR IMAGE TUBE**[75] Inventor: **Alvin D. Schnitzler**, Camp Springs, Md.[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.[22] Filed: **Oct. 11, 1973**[21] Appl. No.: **405,731**[52] U.S. Cl. **313/368; 250/333; 313/96; 313/99; 313/101; 313/386; 313/390**[51] Int. Cl. **H01j 31/12**[58] Field of Search **313/65 R, 65 AB, 67, 68 A, 313/94-96, 99, 101, 368, 366, 367, 384-390; 250/332, 333**[56] **References Cited****UNITED STATES PATENTS**

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[57] **ABSTRACT**

An electronic imaging device of the multigrid type having a novel photo-cathode that is uniformly flooded with a bias light on the front surface, or grid side, and is adapted to emit a flow of electrons from the front surface in direct proportion to a pattern of infrared light incident on the back surface of the photocathode. The photocathode comprises a mosaic of discrete electrically isolated photodiode-photoemitter islands with external grids adjacent to and separated from the photoemitter islands and an antireflection coating on the back surface of a P-type substrate portion of the photodiode. A mosaic of evenly spaced N-type islands are contiguous with the P-type material with a layer of insulation deposited on the front side of the P-type substrate surrounding the N-type islands. Discrete photoemitter islands are contiguous with the N-type islands, or are contiguous with a metallic layer deposited directly on the N-type islands, with each of the discrete photodiode-photoemitter islands being discrete and electrically isolated on the photoemitter side of the substrate.

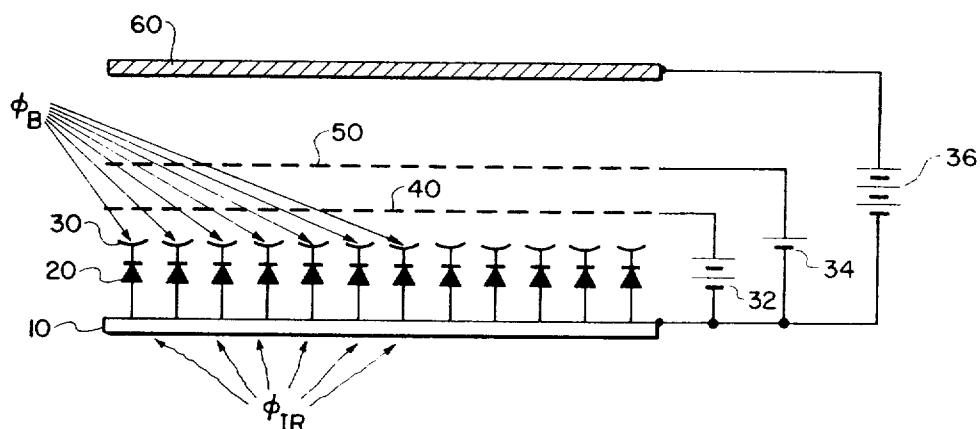
8 Claims, 4 Drawing Figures

FIG. 1

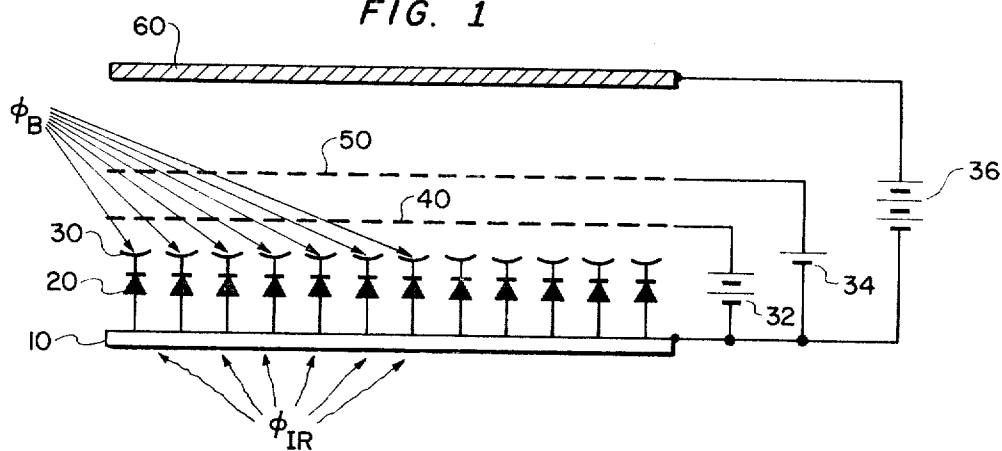


FIG. 2

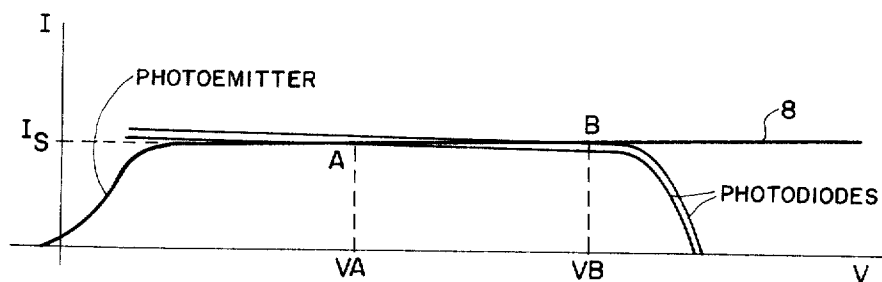


FIG. 3

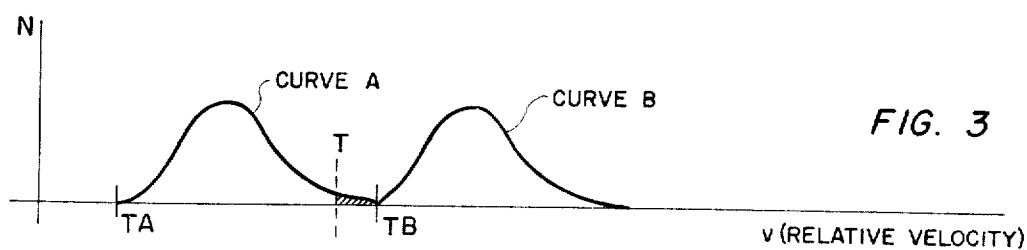
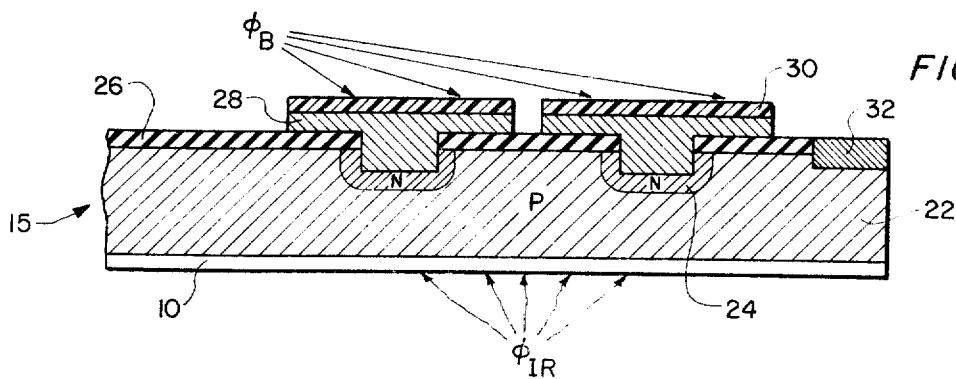


FIG. 4



PHOTODIODE CONTROLLED ELECTRON VELOCITY SELECTOR IMAGE TUBE

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to me of any royalty thereon.

BACKGROUND AND SUMMARY OF THE INVENTION

This invention is in the field of electronic imaging devices which rely on the use of electron velocity selector image tubes containing a photocathode electron emitter and two or more control grids, and especially to multiple grid control of photoemitted electrons in velocity distribution from a mosaic of discrete electrically isolated photodiode-photoemitter islands.

Electronic imaging devices are known that use an array of light sensitive photodiode elements that control the number of electrons emitted from a photoemitter surface according to the pattern of incident light on the sensitive photodiode elements. The pattern of incident light striking a substrate, made of one polarity type diode material, creates electron-hole pairs therein that is in direct relation to the intensity of light in the light intensity pattern. An array of small patches of opposite polarity type material is formed into the one polarity type diode material on the opposite side of the substrate from which the incident light strikes, with these small patches forming P-N junctions with the substrate. Electrons from the electron-hole pairs diffuse to the vicinity of the P-N junction causing a decrease in the reverse bias junction potential, thus resulting in an equal electron accelerating potential increase between the grid closest to the photoemitter surface and the small patches on the photocathode. The prior art devices have the undesirable characteristic that these patches are not electrically isolated from each other.

The present invention is an improved photoconductive layer used in multiple external grid electron image tube comprising a mosaic made up of a plurality of reverse biased electrically isolated photosensitive junctions, or photodiodes, with each junction being in contact with a single photoemitter of a mosaic of discrete electrically isolated photoemitters. A bias light source is positioned on the grid side of the photoconductive layer so that the face of the discrete photoemitters are evenly flooded with the bias light to produce current saturation. An incident infrared image is projected through an antireflection coating into a P-type substrate that forms one side of the photodiode. An insulator layer on the opposite side of the substrate from the antireflection coating isolates the islands of N-type material interspersed therein. Each of the islands of N-type material has a thin metal layer deposited thereon with the thin metal layer contiguous with a photoemitter layer. The incident infrared light image on the P-type substrate creates a number of electron-hole pairs within the substrate in direct proportion to the localized intensity of the light image. These electron-hole pairs cause positive charges (holes) to accumulate at the P-side of the P-N junction and negative charges (electrons) to accumulate at the N-side of the P-N junction, thus decreasing the reverse bias junction potential and increasing the relative potential between the constant potential grid that is closest to the photoemitters and the lowered potential on the discrete photoemitter island. Concomitantly, electrons leaving the

photoemitters islands are velocity increased with the resulting increase in electronic current passing the selector grid and striking the electroluminescent screen. By biasing the photodiode-photoemitter islands to an operating point in the current saturation region of the current-voltage characteristics of both the photoemitter islands and the reverse biased diodes and flooding the front surface of the photoemitters with the bias light, the image tube yields a very high gain that responds according to the input image.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating the components and bias voltages connected thereto of the present inventive device;

FIG. 2 illustrates a current voltage curve representing the amount of electronic current from a single photoemitter that passes the extraction grid versus the extraction grid potential relative to the photoemitter island potential;

FIG. 3 is a qualitative plot of the velocity distribution of the electrons emitted from the photoemitter islands when the extraction grid has two different potentials thereon; and

FIG. 4 illustrates a sectional view of the substrate comprising the discrete electrically isolated photodiode-photoemitter islands of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a schematic diagram illustrating the components of the present invention with the voltage sources connected thereto. Generally, all of these components are enclosed in a glass enclosed vacuum environment (not shown), with the exception of voltage sources 32, 34, and 36 which are outside the vacuum environment but have their electrical leads connected to the components inside. The infrared and bias light sources may be inside, or outside and projected through a transparent vacuum environment. An image of infrared radiation, represented by ϕ_{IR} , originates from an infrared target source (not shown) and passes through a clear glass portion of the glass enclosed vacuum environment. A bias light, or perhaps two or more bias lights, are placed inside the enclosed vacuum environment and project a uniform flood of bias light, represented by ϕ_B , on the mosaic of photoemitters 30. Extraction grid 40 and selector grid 50 have such opened spaces between their wire meshes that bias light ϕ_B is not impeded when passing therethrough. Electrons that are drawn from the photoemitters 30 pass through extraction grid 40 and selector grid 50 to strike electroluminescent screen 60 at the opposite end of the image tube from the incoming target source image.

Voltage source 32 provides a positive voltage on extraction grid 40 with reference to the voltage on the antireflector layer 10, which is at ground potential. Antireflection layer 10 is also the reference potential for voltage sources 34 and 36. Voltage source 34 places a positive voltage on selector grid 50, which is less positive than the voltage on extraction grid 40. Voltage source 36 places a much more positive voltage on screen 60 than exists on extraction grid 40. The voltage of 32 is selected with a positive potential that is almost, but not quite, high enough that electrons will be drawn from the photoemitters 30 with bias light radiation ϕ_B flooding the surfaces of the photoemitters 30. How-

ever, only when an infrared image ϕ_{IR} is projected through the antireflection layer 10 into the photodiodes 20 will electrons be drawn from photoemitter surfaces in direct relation to the intensity of the infrared image on each corresponding photodiode. With each of the photodiode-photoemitters islands being discrete and electrically isolated from each other, an electron image is emitted from the mosaic of discrete electrically isolated photoemitters that is a reproduction of a radiation image projected from the incoming target source onto the P-type substrate.

Refer now to FIG. 4 for an explanation of the semiconductor photocathode, which comprises the antireflection layer 10, the photodiodes 20 formed by P-type substrate 22 and N-type islands 24 and the photoemitters 30. Keeping in mind that the antireflection layer 10 is at ground potential and extraction grid 40 is at a high positive voltage and that increased infrared radiation ϕ_{IR} lowers the resistance across photodiodes 20, the potential on each photoemitters 30 is lowered when the infrared radiation is increased at the input side thereof. Thus, when the infrared radiation is increased, the electron accelerating potential difference between the photoemitters 30 and extraction grid 40 is increased. In the conventional operation of reverse biased photodiodes, such as infrared photodiode detectors, the current thereacross increases in proportion to the incident radiation thereon. However, the present photocathode is different since the current is limited by the extraction of electrons by grid 50 when the photoemitter current is saturated. Therefore, instead of an increase in photodiode current with increased irradiation, there is a decrease in potential across the photodiode junction. This decrease in potential across the photodiode junction results in an equal increase in potential of selector grid 50 relative to the photoemitter islands 30 allowing more of the saturated photoemitter current to flow to screen 60. The photoemitter islands are in series with the irradiated photodiodes formed by the junction of P-type material substrate 22 and N-type material islands 24. Substrate 22 and islands 24 may be made of silicon or germanium to provide near infrared sensitivity. Other materials that may be used for the photodiodes which will provide sensitivity in the intermediate infrared and from which P-N junctions are readily fabricated include indium arsenide and indium antimony. With the voltage on selector grid 50 more positive relative to the photoemitter islands 30, more electrons pass through grid 50 to strike electroluminescent screen 60, preferably made of phosphor, and produce an increase in brightness. Thus, the infrared image on the photodiode mosaic 20 is reproduced and intensified on screen 60.

The semiconductor layer 15 of FIG. 4 is produced in the following manner. After the antireflection layer 10, made of some material that is well known in the art, is deposited on the input side of P-type material substrate 22, N-type material islands 24 are etched on the output side of substrate 22. A silicon layer is then deposited through a mask on the output side of substrate 22 leaving the N-type material islands 24 exposed but covering the remainder of substrate 22. The silicon layer is then oxidized to form an insulator layer 26. Metal islands 28 are then deposited through a mask onto the N-type material islands 24. Metal islands 28 may be made of gold. A thin layer of photoemissive material, such as cesium antimonide or cesiated silicon, is then deposited

through a mask over metal islands 28 to form photoemitter islands thereon. Each of the contiguous N-type material islands 24, metal islands 28, and the photoemitter islands 30 are electrically isolated from the islands adjacent thereto to form discrete photodiode-photoemitter islands. An ohmic contact 32 surrounds the output side of semiconductor layer 15, with only a small part shown since FIG. 4 is a partial sectional view. The ohmic contact is a return path to replenish electrons in the P-type substrate.

FIG. 2 illustrates curves that represent current from a single photoemitter island that passes the extraction grid 40 as a function of extraction grid-to-photoemitter island relative potentials. Also, a load curve 8 of a reverse biased photodiode is plotted for no infrared signal irradiation and is plotted for large infrared signal irradiation. Operating point A on curve 8 corresponds to conditions with no signal irradiation, and operating point B on curve 8 corresponds to conditions with relatively high infrared signal. The voltage between the extraction grid 40 and the photoemitter island 30 is represented by voltage VA when there is no incident infrared radiation on the photodiode 20 associated with the photoemitter island 30. However, when the incident infrared radiation signal is relatively high, the voltage between extraction grid 40 and the photoemitter islands 30 is represented by voltage VB, which is a large increase from voltage VA.

It is apparent that large potential changes will occur when conditions are such that the saturation current of the photoemitter island equals the leakage current of the reverse biased photodiode at a junction voltage where the leakage current versus junction voltage curve has the smallest slope.

FIG. 3 shows qualitatively the velocity distribution of the photoemitted electrons. Referring to FIG. 1 along with FIGS. 2 and 3, when the extraction grid-to-photoemitter island potential is VA, only the shaded portion of the velocity distribution curve A corresponds to electron energies sufficient to pass selector grid 50, i.e. the threshold velocity at point T for electrons to pass grid 50. Velocity distribution curve B corresponds to electron energies sufficient to pass selector grid 50 when the potential on extraction grid 50 relative to the photoemitter 30 is at voltage VB. It can clearly be seen that when a photodiode 20 is irradiated with high infrared energy, the extraction grid-to-photoemitter island potential increases to VB and that the potential VB is more than sufficient to allow all of the electrons emitted from the photoemitter to pass selector grid 50.

It should be understood, of course, that the foregoing disclosure relates to only a preferred embodiment of the invention and that numerous modifications or alterations may be made therein without departing from the spirit and the scope of the invention as set forth in the appended claims.

I claim:

1. A photodiode controlled electron velocity selector image tube in a vacuum envelope comprising:

a P-type material substrate having a plurality of electrically isolated photosensitive junctions comprising a plurality of evenly spaced N-type material islands on a front side of said P-type material substrate and a layer of electrical insulation contiguous with the entire front side of said P-type mate-

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rial substrate but only around the periphery of said N-type material islands;

a solid antireflection coating contiguous with a back side of said P-type material substrate;

a plurality of discrete thin metal islands contiguous with said N-type material islands and said layer of electrical insulation wherein said thin metal islands are spread over said layer of electrical insulation in close proximity to but electrically isolated from each other;

a plurality of discrete electrically isolated photoemitters contiguous with and covering the entire lateral surface of said plurality of discrete thin metal islands wherein said plurality of electrically isolated photoemitters are serially connected to said plurality of electrically isolated photosensitive junctions through said plurality of thin metal islands with each related photosensitive junction and photoemitter forming a plurality of discrete photocathode elements;

an electroluminescent screen;

a plurality of fine mesh grids positioned between said plurality of discrete electrically isolated photoemitters and said electroluminescent screen;

a voltage divider source having voltage taps therefrom connected in step up voltage from said antireflection coating through said plurality of fine mesh grids to said electroluminescent screen for velocity controlling the electrons emitted from said discrete electrically isolated photoemitters to said electroluminescent screen;

a bias light source for uniform illumination of the front surface of said plurality of discrete electrically isolated photoemitters for producing electron current saturation therefrom; and

an infrared image radiation source for projecting an image on said antireflection coating such that the

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resistance across each of said plurality of electrically isolated photosensitive junctions is in direct relation to the intensity of said radiation source image to cause a change in velocity of electrons emitted from each of said plurality of photoemitters with relation to the fixed voltages on said plurality of fine mesh grids, and wherein said plurality of discrete thin metal islands inhibits said bias light illumination from entering said plurality of N-type material islands yet allows easy movement of electrons from said N-type material islands into said photoemitters.

2. A photodiode controlled electron velocity selector image tube as set forth in claim 1 wherein said plurality of discrete electrically isolated photoemitters are made of cesium antimonide.

3. A photodiode controlled electron velocity selector image tube as set forth in claim 1 wherein said plurality of discrete electrically isolated photoemitters are made of cesiated silicon.

4. A photodiode controlled electron velocity selector image tube as set forth in claim 1 wherein said electroluminescent screen is phosphor.

5. A photodiode controlled electron velocity selector image tube as set forth in claim 4 wherein said both N-type material and said P-type material is silicon.

6. A photodiode controlled electron velocity selector image tube as set forth in claim 4 wherein said both N-type material and said P-type material is germanium.

7. A photodiode controlled electron velocity selector image tube as set forth in claim 4 wherein said P-type material is indium and said N-type material is arsenide.

8. A photodiode controlled electron velocity selector image tube as set forth in claim 4 wherein said P-type material is indium and said N-type material is antimony.

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