United States Patent

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[54] **A CAMERA TUBE WITH POROUS SWITCHING LAYER**
11 Claims, 3 Drawing Figs.

[52] **U.S. Cl.**.. **315/11,**
313/65, 313/68, 313/72

[51] **Int. Cl.**.. **H01j 31/26,**
H01j 31/48

[50] **Field of Search**.. 313/65 AB,
66, 67, 89; 315/10, 11

[56] **References Cited**

UNITED STATES PATENTS

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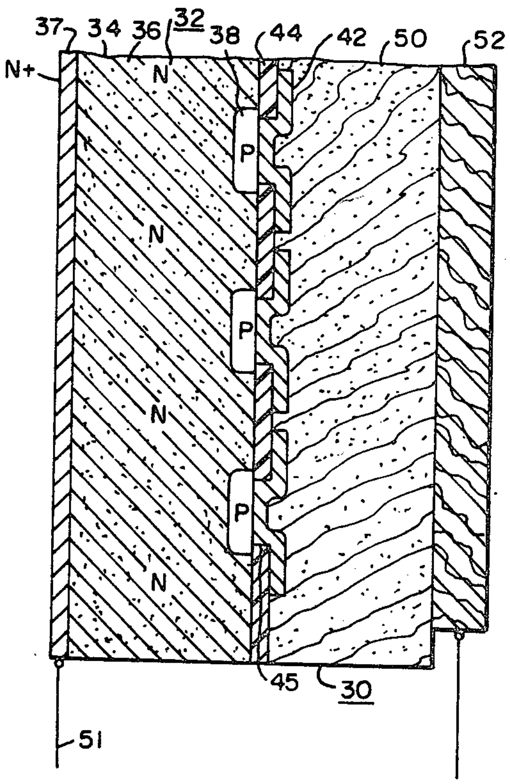
ABSTRACT: A camera tube in which input radiation information is directed onto a radiation-sensitive target or the input radiation is converted to electrons directed onto an electron-sensitive target and the information is read out from the opposite side of the target by means of a high-energy electron beam.



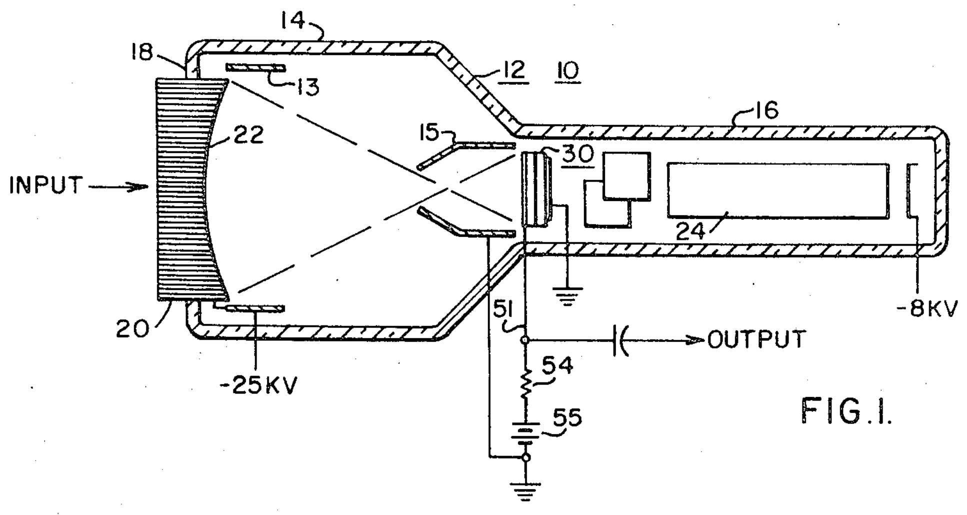


FIG. 1.

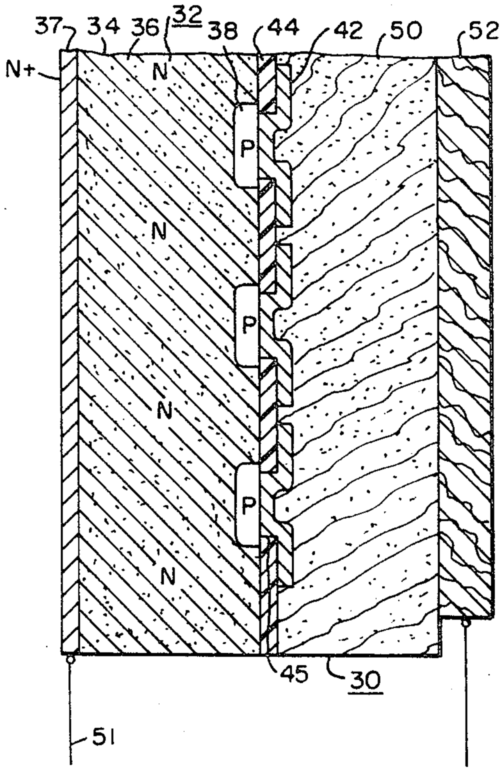


FIG. 2.

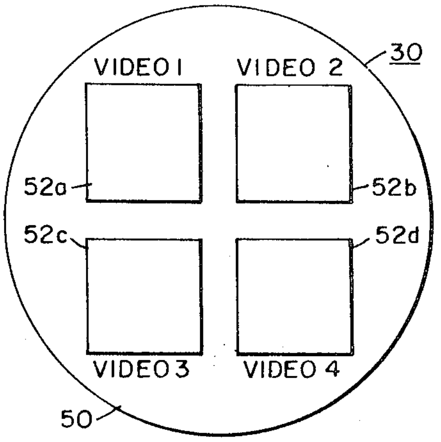


FIG. 3.

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A CAMERA TUBE WITH POROUS SWITCHING LAYER

BACKGROUND OF THE INVENTION

This invention is directed to camera tube devices incorporating a semiconductor target structure responsive either to electron bombardment or light radiation and in which the information is read out from the opposite side of the semiconductor target. There are several types of camera tubes incorporating semiconductive target members such as those in which the input radiation is converted into an electron image which is directed onto the semiconductor target. One specific example of this type of device is known as the Electron Bombardment Induced Conductive type tube in which the input radiation is converted by means of a photocathode to a writing electron beam which is in turn directed onto a semiconductor layer which exhibits change of conductivity in response to electron bombardment. The writing beam passes through a conductive layer into the dielectric target and the image is read out by the utilization of a reading beam.

Another type of tube in this same area is the Secondary Electron Conductive type camera tube (SEC) in which the light image is again converted to an electron image by a photocathode and the electrons are directed onto a target. The target includes a conductive layer and porous semiconductor material which generates a charge image at the exposed surface and the image is read out by means of a reading electron beam.

There are also several other cameras on the market in which the radiation is directed onto a semiconductor target which responds to the radiation in generating a charge image on the semiconductor target. A vidicon is a typical example of this type of structure and a recently developed type tube such as described in U.S. Pat. No. 3,011,089 and is generally referred to as a silicon diode array target utilizing an array of reversed biased diodes. The reversed bias silicon diode array target is characterized by electron gains which are more than 10 times greater than the SEC target, is compatible with standard tube-processing techniques and provides adequate frame storage by virtue of its high capacitance and low reverse bias current.

The target in a camera tube may be represented in a general way by a semiconductor on an electrically conductive backplate. The semiconductive layer which is the sensing layer of the target has the properties normally of an insulator in the unexcited state but becomes conducting when excited by radiation such as light, electrons and X-rays. The backplate must be transparent to the exciting radiation. The reading beam at frame-time intervals charges each element of the free surface to some equilibrium potential. During the frame-time, each element discharges by an amount determined by the intensity of excitation. The charge q which the scanning beam has to deposit on each element in order to bring it back to equilibrium potential generates the video signal which appears as a voltage across an output resistance R connected to the conductive backplate. This voltage is equal to the voltage across the output resistance R which is equal to $R\times dq/dt$, where t is the effective time duration of the beam on each element.

In the low-velocity scanning mode, the electrons charge the sensing layer to an equilibrium potential, normally equal to that of the cathode potential, by landing at velocities below that of the first crossover potential of the sensing surface. As the surface approaches equilibrium, the landing velocities approach zero. Secondary and reflected electrons are completely removed from the target by the field surrounding the target. Magnetic focusing of the reading beam is commonly used and is highly desirable and provisions to insure normal beam landing are an absolute necessity in order to minimize defocusing and shading because the normal velocity components are of the same order as the transverse. Only a small fraction of the available cathode electrons are used because as equilibrium is approached, the beam impedance is independent of the total beam current. Raising the beam current may actually increase the impedance resulting in an increase in capacitive lag because of the concomitant increase in effective beam temperature. In spite of its problem, the low-velocity scanning mode is universally used at the present time because it yields the best overall picture quality.

In the high-velocity scanning mode, the electrons charge the sensing layer surface to an equilibrium potential nominally equal to that of the surrounding potential which may be the wall or an accessory grid positioned in front of the second layer. The electrons land at velocities above crossover and therefore the target charges in a positive direction. Regardless of the surface potential, the beam always lands, for example, at nominally 300 volts, thus remaining in good focus, even for nonnormal landing, because the lateral velocity components are small compared to the normal velocity components. Beam impedance, and therefore capacitive lag can be made arbitrarily low by sufficiently increasing the total beam current. As the surface approaches equilibrium potential, only those secondaries admitted in a near-normal direction are removed from the target. The remainder are returned to the target and land below first crossover where they produce spurious signals such as a nonuniformity of the dark current and inhalation. Furthermore, surface defects or foreign matter, or any other conditions which can result in local variations in the secondary emission of the scanned surface appear in the image.

It is accordingly a general object of this invention to provide a silicon diode type target which is sensitive to writing information in forming an electron image. It is another object of this invention to provide an improved camera tube which incorporates a switching layer between the reading beam and the target to permit the utilization of a high-energy reading beam.

SUMMARY OF THE INVENTION

The invention is directed to a camera tube device utilizing a semiconductor type target utilizing a switching type layer between the reading beam and the target to permit the utilization of high-energy electron reading beams without secondary redistribution problems and also provide a semiconductor target structure utilizing a diode array arrangement in which the image is written into the target by means to an electron beam and is read out on the opposite side by means of an electron beam.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a camera tube in accordance with one embodiment of the invention;

FIG. 2 is an enlarged view of the target shown in FIG. 1; and

FIG. 3 is a front view of a modified target.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring in detail to FIG. 1, there is shown a television camera tube **10** comprising an evacuated envelope **12** having a large tubular portion **14**, referred to as the image section and a neck portion **16**. An input window **18** is provided on the image section end of the tube. The input window **18** may include a fiber optic transmission window **20** having a photoelectric surface **22** on the inner surface of the fiber optic window **20**. A suitable electron gun **24** is provided in the neck portion **16** of the envelope and generates a scanning electron beam which may be directed onto a target member **30**. A suitable lens system is provided for focusing and accelerating the electron image from the photocathode **22** onto the target **30**.

The target structure **30** is shown in more detail in FIG. **2**. The target **30** consists of a suitable radiation-sensitive material responsive to electron bombardment. In the specific embodiment shown, the sensing layer **32** is silicon diode array and is comprised of a semiconductor wafer **34**. The wafer **34** is comprised of a major portion of which is an N-type substrate **36** with isolated P-type regions **38** forming a mosaic on the surface of the semiconductor wafer **34** facing the electron gun

24. The semiconductor wafer **34** may be of a suitable N-type silicon material having a resistivity of about 5 ohms centimeter. The wafer **34** may be of any desired diameter but should have a thickness of less than 200 microns after the wafer **34** has been chemically polished on both faces. A layer **44** of silicon oxide of a thickness of about 4,000 angstroms is grown by thermal oxidation at a relatively high temperature of 1,100° C. in an oxidizing atmosphere. The oxide coating **44** is then removed selectively using photolithographic techniques to open windows **45** in the oxide coating **44**. Diffusion of the diode array is accomplished by deposition and a drive-in cycle using a suitable material such as boron to form the P-regions **38**. The normal junction depth of the P-type regions **38** is about 5 microns. The diode regions **38** may be spaced on 25 microns centers. The next step is a P_2O_5 gettering process on the opposite surface of the wafer **34** to remove deep-lying impurities and also from an N+ layer **37** which provides an ohmic contact. The next step in the manufacture is to provide the metal contacts **42** over the diodes. This may be accomplished by metallization consisting of a layer of aluminum evaporated onto the wafer **34** and then selectively removed by photolithographic techniques. The square metal contact **42**, about 20 micron on a side, is left on each diode. This leaves a spacing of about 5 microns between the contacts **42**.

A switching layer **50** is provided over the semiconductor wafer **34** on the face thereof facing the scanning electron gun **24**. The layer **50** may be provided by evaporating a suitable material in an inert gas to provide a porous structure. A suitable material is an alkali halide such as KCl, BaF_2, NaCl, LiF, MgO_2 or CsI. For example, the layer **50** may be KCl evaporated to a thickness of about 20 microns in a suitable inert atmosphere such as argon or nitrogen at a pressure of 0.5—5 millimeters of Hg. The thickness of the layer **50** which may be 10 to 40 microns would have a density of about 1—3 percent of its normal bulk density. The density of the layer **50** should be less than 10 percent of normal bulk density. An equilibrium layer **52** is evaporated onto the porous layer **50** and this may be of a suitable electrically conductive material such as gold. The equilibrium layer **52** may also be evaporated in an inert gas so as to provide a gold-black deposit which is also porous or sooty type deposit having a thickness of about 3—10 microns and a density of about 1—3 percent of bulk density. The density should be less than 10 percent of normal bulk density. This layer provides an electron-transmissive layer and a good electrically conductive layer. The layer **52** is supported on the surface of the porous layer **50** and without any appreciable penetration into the porous layer **50**. The particle or agglomerate size of the material in layer **52** is larger than that in layer **50**. The inherently high visible and infrared radiation absorption properties of the gold-black layer **52** serves to shield the layer **50** and the sensing layer **32** from any stray light produced by the scanning electron gun **24**.

In the operation of the device, input radiations are directed through the input window **20** onto the photocathode **22**. The input radiations cause the photoelectric layer **22** to generate an electron image corresponding to the radiation input. This electron image generated by the photocathode **22** is directed by suitable electrostatic focusing means such as electrodes **13** and **15** onto the target **30**. The electrons are accelerated by a potential of about 25 kilovolts and penetrate into the semiconductor substrate **36**. The electrons create a plurality of hole electron pairs within the substrate **36**. The electron beam from the electron gun **24** scans the opposite surface of the target **30**. The cathode of the electron gun may be at a negative potential of about 8,000 volts with respect to the target **30** and above first crossover potential of the layer **52**. The high-velocity electrons lose the greater part of their energy within the layer **50**. The high-velocity electrons generate secondary electrons into the voids of the porous layer **50**. These secondary electrons flow through the voids in the layer **50** in response to an electric field. Each scanned and penetrated region of the layer **50** becomes momentarily conducting and therefore acts as a switch which connects and therefore returns each associated element **42** to an equilibrium potential which is normally equal to the potential applied to the conducting layer **52**. In a specific example shown, the layer **52** is at ground and the electrode **37** is at a positive potential of 10 volts. A voltage of 10 volts is applied across the sensing layer **32**. This applies a reverse-bias across the P+N diodes **36** and **38**. During the frame-time each element **42** discharges in the usual manner by an amount determined by the intensity of excitation radiation from the photocathode **22**.

The high-energy electrons about 5 to 25 Kev. from the photocathode **22** penetrate into the wafer **32** and generate electron-hole pairs. The holes diffuse to the diode space charge region. This reduces the charge on the contacts **42** to a potential between ground and 10 volts positive. The recharging of the contacts **42** to equilibrium in this case by the switching layer **50** generates the video signal which appears across the resistor **54**. Since the current carried by the transport of the free secondary electrons in the porous switching layer **50** can be on the order of a 100 times greater than the primary beam current of the beam generated by the gun **24**, extremely modest emission demands are made of the cathode of the gun **24**.

It is therefore obvious that the scanning electron beam from the gun **24**, the equilibrium layer **52** and the electrode **37** maintain the sensing layer **32** in a reversed diode situation so that the target **30** provides a sensing layer. The high-energy electrons entering the target **30** from the photocathode **22** generate electron-hole pairs. The holes are swept across the depletion region to the diode P-type conductivity region **38** and contributes to the total leakage current of the diode. The total holes reaching the diodes during an exposure interval, partially discharge the diode and provide charge proportional to the integrated local intensity of the input radiation. It is found that in such a target an amplification greater than 1,000 is obtainable.

The preferred embodiment of the device is shown in FIGS. **1** and **2**. The silicon diode array type of sensing layer provides for desirably high gain and high capacitance while the switching layer **50** provides for desirable fast readout for a high-velocity beam. It is possible to utilize proximity focusing between the photocathode **22** and target **30** and also it is possible to provide some type of electron multiplier such as a channel multiplier between the photocathode **22** and the target **30**.

It is also possible that the backplate electrode **37** could be connected directly to ground and the video signal derived from the equilibrium electrode **52** through an output resistor connected to a negative potential source. Such an alternative is particularly useful for the configuration shown in FIG. 3 where multiple video channels are to be derived from a signal sensing layer. As an example, equilibrium electrode **52** is broken into four separate members **52***a—d*. The structure in FIG. 3 would be useful for high resolution, real time application where the magnitude of the bandwidth of the signal video channel would be prohibitive. Another modification is to substitute an SEC-type sensing layer for the diode array so that the combination SEC layer provides both sensing and switching. Free secondary electrons generated in the sensing portion of the SEC layer by the radiation input electrons while the free electron generated in the switching portion of the SEC by scanning beam electrons acts as the switching function. It is also obvious that the switching layer could be entirely removed and direct readout made of the layer by use of the electron beam on the diode array with the electron energy activating the diode array. In addition other sensing types layers other than the silicon diode array and the SEC type layer could be substituted and the switching layer described above utilized in combination.

The video signal-to-noise ratio is an inverse function of ratio of the loading capacitance of the video amplifier input circuit to the capacitance square centimeter of the sensing layer **32**. The loading capacitance is the sum of the capacitance of the target structure, the wiring and the amplifier input and is typically about 40 picofarads for conventional vidicons and SEC camera tubes operating into modern preamplifier. In the switching layer target, the dominant loading capacitance is, to the first order, the capacitance of the switching layer **50**. In order to keep this capacitance as low as possible, a relatively thick switching layer **50** should be used. For a typical switching layer (100 grams/cm.^{2} of KCL) the capacitance is about 60 picofarads/cm.^{2} independent of operating voltage. For the high-capacitance sensing layers used with conventional scan, the signal-to-noise ratio is already so high that its reduction due to the switching layer would be of no consequence. For the relative low capacitance SEC type layer however, the reduction might be of consequence under certain circumstances. It is obvious that other modifications may be made without departing from the spirit of this invention.

I claim as my invention:

1. An electron discharge device comprising

a storage target responsive to excitation to generate a charge image, means for directing writing excitation information onto a first side of said target to establish a charge image on a second side of said target,

means for directing a reading electron beam toward said second side of said target to derive a signal representative of said charge image, said reading electron beam operated at a potential above the first crossover potential of the surface bombarded by said reading electron beam,

a switching member provided on said second side of said target intercepting said reading electron beam, said switching member responsive to said reading beam to generate an amplified electron flow to read out said charge image on said target, said switching member comprises a porous coating of an insulating material having a density of less than 10 percent of its normal bulk density and exhibiting the property of generating secondary electrons into the voids of said layer in response to bombardment by electrons from said reading electron beam and conduction of said secondary electrons through the voids in response to an electric field.

2. The device in claim **1** in which a porous electrically conductive coating is provided on the surface of said porous insulating material remote from said target.

3. The device in claim **2** in which an ohmic contact is provided to said first side of said target.

4. The device in claim **3** in which said storage target comprises a semiconductor material containing an array of insulatingly spaced rectifying junctions.

5. The device in claim **4** in which a reverse bias is applied across said junctions by means of said ohmic contact and said reading electron means.

6. The device in claim **5** in which said bias is modified in response to said writing excitation and an output signal corresponding to said writing excitation is derived by said reading beam.

7. The device in claim **6** in which said output signal is obtained from said ohmic contact.

8. The device in claim **6** in which said output signal is obtained from said porous electrically conductive coating.

9. The device in claim **1** in which storage target comprises a semiconductive material containing an array of insulatingly spaced P–N junctions.

10 The device in claim **1** in which said writing excitation is input light radiations.

11. The device in claim **1** in which said writing excitation is electrons generated in response to input radiation.