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HIGH GAIN STORAGE TUBE WITH BIC TARGET

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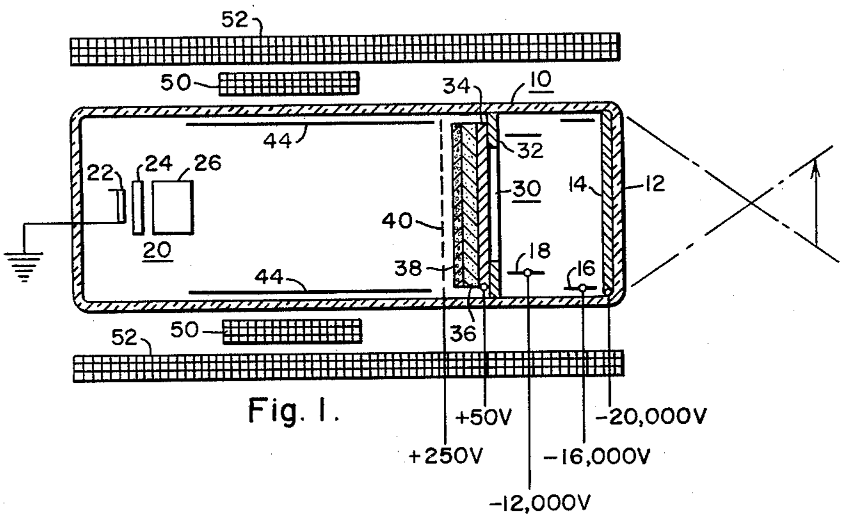

Fig. 1.

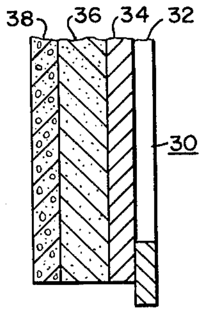

Fig. 2.

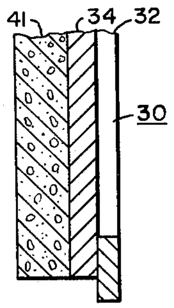

Fig. 3.

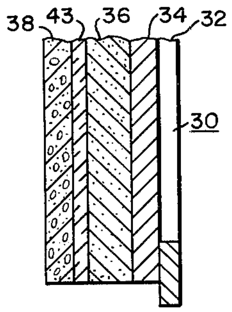

Fig. 4.

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HIGH GAIN STORAGE TUBE WITH BIC TARGET

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This invention relates to electron discharge devices and more particularly to those having storage target electrodes therein.

One well known type of storage target electrode tube utilizes a storage target employing the principle of electron bombardment induced conductivity (EBIC). The EBIC type of storage tube consists of a writing section provided on one side of the storage target and a reading section on the opposite side. The writing section may be in the form of a large area photocathode in which an electron image is directly imposed on the target or may consist of an electron gun in which the electron beam is focused and deflected over the target member. The reading section provided on the opposite side of the target with respect to the writing section includes a scanning electron gun for producing at least a medium velocity electron beam which is focused and deflected over the target member.

The target structure of the EBIC type of tube consists of a very thin layer of high resistive material deposited on the read side of a backplate member. The backplate member is a layer of an electrically conductive material which provides transmission of the incident writing beam electrons. The thin layer of high resistive material may be referred to as the storage layer. The scan read beam may be operated at such a potential that the emission of secondary electrons from the storage layer is greater than unity. This tends to charge the surface in a positive direction until the potential reaches an equilibrium value. The opposite side of the storage layer is in physical and electrical contact with the backplate. The backplate may be operated at a negative potential with respect to the equilibrium potential on the exposed surface of the storage layer. This results in a difference in potential existing between the two surfaces of the storage layer during conditions of equilibrium. During the writing operation, the high velocity electron beam bombards the target and passes through the backplate and penetrates the storage layer. The resulting electron bombardment induced conductivity produced in the storage layer lowers the potential of the exposed surface of the storage layer by varying degrees toward the negative potential of the backplate. The front surface of the storage layer thus acquires a pattern of potential variation which corresponds to the input video signal.

When the writing beam is removed, the storage layer gradually returns to its normal resistivity. The output signal derived from any given area of the storage area by the reading gun is a function of the input signal, providing that the area is not written beyond saturation, and storage of a continuous range of half tone information is possible. The reading gun beam is scanned over the exposed surface of the storage layer and a storage surface element that has been driven toward the negative backplate voltage by the writing beam is bombarded by electrons above first crossover. The secondary electrons may be collected by an output electrode adjacent the exposed surface to constitute the output signal current. The reading process, therefore, serves as an erasing process by removing the stored potential pattern and driving the storage surface back to equilibrium value. The storage layer does not immediately regain its normal resistivity after the writing beam is removed and a large number of scans may be required before equilibrium value is reestablished. This may be referred to as the image lag or persistence.

The EBIC type of tube provides an inherent gain within the target itself. The gain associated with this tube is obtained by the conversion of the energy of the relatively few high velocity writing electron into the energy necessary to lift many electrons from the valence band to the conductivity band of the storage target material. In this respect, the theoretical gain achievable is proportional to the energy employed to accelerate these electrons. For example, if V_p represents the electron volt energy used to accelerate the primary electrons, V_g represents the electron volt energy associated with the excitation of a carrier across the forbidden gap, and θ represents the efficiency conversion factor of the EBIC target employed, then the achievable EBIC gain is given by $V_p(\theta)/V_g$. Thus for 20 kilovolt primary electrons, and a band gap of 2 electron volts, the theoretical achievable gain assuming 100 percent conversion efficiency is equal to 10,000. In the interest of completeness, it should be pointed out that an additional photoconductivity type gain is possible in geometries where replenishment of charge carriers to the EBIC material can take place. In general, the EBIC targets suitable for use in practical pickup devices have had gains between 300 to 800. The conversion efficiency factor thus has in general been less than 10 percent for practical EBIC materials.

It is accordingly the general object of this invention to provide a new and improved electron discharge device incorporating a storage electrode which provides high amplification of the input signal.

It is another object to improve the efficiency of the conversion factor θ of a conventional electron bombardment induced conductivity target by utilization of other mechanisms than direct EBIC action to produce additional target gain.

It is another object to provide a new and improved target structure in which information impressed on an electron beam may be written onto the target and then read out at a later time by an electron beam.

Briefly, the present invention accomplishes the above cited objects by providing a target structure comprised of a storage material which exhibits the property of electron bombardment induced conductivity and additional gain mechanisms. In addition to EBIC, the material of the target exhibits the property of emitting light in response to electron bombardment and additional property of utilizing this light to enhance the EBIC effect due to photoconductivity mechanisms. In this manner substantial gains have been obtained over those previously realized in electron bombardment induced conductivity materials.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in claims annexed to and forming a part of this description.

For a better understanding of the invention, reference may be had to the accompanying drawings in which:

FIGURE 1 is an elevational view in section schematically representing a pickup tube and associated system in accordance with the teachings of this invention;

FIG. 2 is an enlarged elevational view in section, illustrating the electrode target assembly in FIG. 1;

FIG. 3 is an elevational view in section of a modified electrode target assembly that may be embodied in the tube shown in FIG. 1; and

FIG. 4 is an elevational view in section of a modified electrode target assembly that may be embodied in the tube shown in FIG. 1.

Referring in detail to FIG. 1 there is illustrated a pickup tube comprising a glass envelope **10**. At one end of the envelope **10**, there is provided a face plate **12** transmissive to the desired scene radiation and of a suitable material such as glass in the case of visible light. A suitable coating **14** of a photoemissive material sensitive to the input radiations and of a suitable material such as cesium antimony for the case of visible light is provided on the inner surface of the face plate **12**. An electron gun **20** is provided at the opposite end of the envelope **10** for generating and forming a pencil-like electron beam which is directed onto a target **30**. The target member **30** is positioned between the electron gun **20** and the photocathode **14**. Between the target member 30 and the photocathode **14**, there are provided a plurality of electrodes illustrated as **16** and **18** with suitable potentials provided thereon for accelerating and focusing of the photoelectrons emitted from the photocathode **14** onto the target member **30**. Positioned between the target **30** and the electron gun **20**, there is provided a grid member **40** of electrically conductive material such as nickel which is located at a distance of about 0.1 to 0.2 inch from the surface of the target member **30**.

The target member **30**, as shown in FIG. 2, is comprised of a support ring **32** of a suitable material such as Kovar alloy (Westinghouse Electric Corporation trademark for an alloy of nickel, iron and cobalt) having a suitable electrically conductive support film **34** attached to the metal ring **32**. A coating **36** of a high resistive material which exhibits the property of electron bombardment induced conductivity and in addition cathodoluminescence is provided on the surface of the conductive layer **34** facing the scanning electron beam **20**. A porous layer **38** is provided on the layer **36** and is of a material exhibiting the property of electron bombardment induced conductivity and photoconductivity.

Deflection means **50** illustrated as a coil is provided around the envelope **10** for deflection of the electron beam generated by the electron gun **20** and by application of suitable potentials to the deflection means **50** the electron beam may be scanned over the surface of the target **30** in a conventional manner. A magnetic coil **52** is also positioned around the envelope **10** to provide additional focusing of the electron beam from the gun **20** onto the target **30** as well as for focusing the electrons from the photocathode **14** onto the target **30**.

The scanning electron beam gun **20** consists of at least a cathode **22**, a control grid **24** and an accelerating anode **26** for providing a pencil-like electron beam. A conductive coating **44** is also provided on the inner surface of the envelope **10** or in the form of a separate conductive element which aids in focusing the electron beam onto the target **30**.

A specific example of a suitable storage target **30** will now be described. The aluminum film **34** may be formed by the vacuum deposition of aluminum onto a film of thermally removable organic material such as cellulose nitrate. The thickness of the aluminum layer **34** should be about 1000 angstroms for an electrode diameter of about 1 inch. The cellulose nitrate is baked out leaving the aluminum film **34** upon the ring **32**. This technique of fabrication is well known and is described in more detail in U.S. Patent 2,905,844 assigned to the same assignee as this invention. The support layer for the target may also be of the type described in U.S. Patent 2,898,499 assigned to the same assignee as this invention. The support must have sufficient conduction so as to replenish electrons to the target structure.

The aluminum film **34** and supporting ring **32** is then placed in a bell jar having a vacuum of approximately 10^{-5} torr. A boat of a suitable material such as tantalum provided with a resistive element is positioned within the bell jar and at a predetermined distance of about 3 inches from the aluminum. A predetermined amount of material for the layer **36** such as cesium iodide is provided within the tantalum boat and evaporated onto the aluminum layer to provide a layer of a thickness of about 4.5 microns. This provides a vacuum deposit of cesium iodide of normal bulk density.

The film **38** which is a porous or spongy deposit may be deposited by placing the assembly into a bell jar providing an atmosphere of approximately 1 millimeter mercury of argon gas or any other suitable inert gas. A boat of a suitable material such as tantalum is provided with the resistive element and is positioned at a distance of about 3 inches from the target. A predetermined amount of a suitable material such as antimony trisulfide is provided in the boat. The heat is then applied to the boat until the material has just melted at which temperaure the material is then maintained. This temperature is considerably less than the melting point of the material at atmopsheric pressure. The vapor pressure of the material at its melting point under such conditions is found sufficient to cause vaporization of the material at a sufficient rate. The material of the layer **38** is evaporated to completion and it is found that the density of the evaporated material onto the layer **36** is approximately 1 to 10 percent of the normal bulk density of the material. It is found that the porous layer of about 30 to a few hundred micrograms per square centimeter in weight is adequate.

Another specific example of a target which was constructed to demonstrate the feasibility of the device is set forth here. The target included a layer **36** of sodium iodide to a thickness of about 2.7 microns evaporated in a vacuum onto the support conductive layer **34**. The layer **36** of sodium iodide provides an electron bombardment induced conductivity material and in addition cathodoluminescence. This target structure with the single layer **36** demonstrated poor imaging quality and no measurable gain. By depositing a layer **38** of antimony trisulfide to a thickness of **33** micrograms per square centimeter of a porous or smoke deposit resulted in gain of **10**. In both of the above examples, the particular materials employed in layer **36** had low electron bombardment induced conductivity capabilities but did emit light as a result of electron excitation.

Another target constructed utilized a layer **36** of a suitable material such as potassium iodide to a thickness of 4.3 microns evaporated in a vacuum and this resulting structure by itself again demonstrated no imaging gain but exhibited a gain of 200 after evaporation of a layer of 0.9 micron thickness of arsenic trisulfide as a porous layer. This composite target was subjected to a two hour bake at a temperature of 125° C. without injury to the target.

Another target construction included a layer **36** of potassium iodide of a thickness of 4.3 microns of a vacuum deposit which exhibited a gain of about 7.5. By evaporation of a layer of 5 micron thickness of selenium as a vacuum or solid type of layer evaporated in a vacuum, the gain was increased to 1600. The energy of the writing electrons was 20,000 electron volts. The backplate was at a positive potential of 50 volts with the cathode **22** of the gun **20** at a potential of ground to establish a field of about 50,000 volts/cm. across the layers **36** and **38**.

It was also found that evaporation of a 5 micron layer of selenium over a 1.8 micron layer of potassium iodide increased the gain from 80 to 3000. Because of the critical nature of the selenium layer, these particular two targets are quite critical as to the maximum temperatures they will tolerate.

While preferred electron bombardment induced conductive composite targets relate to a combination of alkali halide materials having combined luminescent and electron bombardment induced conductivity characteristics such as potassium iodide, potassium chloride, sodium iodide, potassium bromide and etc. with either antimony trisulfide, arsenic trisulfide or arsenic disulfide have demonstrated good combined EBIC and photoconductive characteristics, the scope of the disclosure is not limited to these materials. For example, more efficient phosphors such as zinc sulfide, cadmium sulfide, willemite and calcium tungstate can also be employed as the combination light emitting layer **36** in FIG. 1. It has also been found that many materials have reasonably high electron bombardment induced conductivity responses. Therefore any combination of efficient photoconductors and cathodoluminescent materials with reasonable electron bombardment induced conductivity either as separate layers or interspersed fall within the scope of this invention. The principal criterion is that the charge carriers should be generated by the combination of electron bombardment induced conductivity and photoconductivity action. It should be noted that the materials in layers **36** and **38** may be interspersed or mixed to provide a single layer **41** as illustrated in FIG. 3. This may be provided by co-evaporation of the two materials.

It is also noted that the materials utilized in the layers **36** and **38** are not limited to those materials which will not react with each other since it is possible to use a very thin electron permeable layer **43** as illustrated in FIG. 4 to separate the layers **38** and **36**. This chemical isolating layer may consist of inert materials such as aluminum oxide, silicon dioxide, magnesium fluoride, glass or even an electron bombardment induced conductivity material which is non-reactive with either layer **36** or **38**. It is only necessary that the layer **43** be thin enough to permit the passage of charge carriers and reasonably permeable to high voltage writing electrons.

In the operation of the device as illustrated in FIGS. 1 and 2, an input radiation scene is directed onto the photocathode **14** to provide photoelectron emission at a rate corresponding to the brightness of each of the elements of the radiation image directed thereon. The photoelectrons are accelerated by a voltage of about 20,000 volts and the photoelectron image may be focused to a reduced size upon the target electrode **30**. The electrons will penetrate through the supporting layer **34**, the layer **36** and substantially through the layer **38**. This writing action of the photoelectrons produces charge carriers within the two layers **36** and **38** causing the elements to become conductive by the well known process of bombardment induced conductivity. In addition, the bombardment of the layer **36** causes the layer to emit radiations in the form of light which are in turn received by the layer **38** causing it to become more conductive due to the well known photoconductive action. In the specific embodiment, a field is impressed across the target layer **30** by maintaining the conductive backing at a positive potential of 50 volts and the gun cathode **22** at a potential of ground. The net result of the combined writing actions is that the negative charge carriers excited by the electron bombardment induced conductivity action go to the positive target backplate **34** which is held at a potential of about 50 volts while holes will tend to migrate to the exposed surface of the layer **38**. In addition, the negative charge characters excited in the layer **38** by the photoconductivity action therein go to the positive target backplate **34** while the holes migrate to the surface of the layer **38**. This tends to charge the surface layer **38** toward the potential of the backplate. The electron gun **30** in scanning the surface of the layer **38** tends to maintain this surface at cathode potential and of course in the operation of restoring the surface to equilibrium potential generates a video signal corresponding to the information written on the target by the photoelectrons. In this operation, the scan gun beam strikes the surface below first crossover. It is obvious that it could operate between first and second crossover as described previously with regard to EBIC type target. The signal may be read out of the target either by conventional image orthicon return beam operation, vidicon type operation in which the signal is derived from the conductive backplate **34** or if desired the signal may be derived from an output signal electrode positioned adjacent the exposed surface of the target and with the backplate operating at a negative potential with respect to the exposed surface of the layer **38**.

While there have been shown and described what are presently considered to be the preferred embodiments of the invention, modifications thereto will readily occur to those skilled in the art. It is not desired, therefore, that the invention be limited to the specific arrangements shown and described and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

I claim as my invention:

1. An electron discharge device comprising a target electrode, said target electrode including a first layer of high resistive material exhibiting the property of electron bombardment induced conductivity and cathodoluminescence, an electrically conductive electron permeable coating provided on one surface of said first layer, a second layer disposed on the other surface of said first layer of a high resistive material exhibiting the property of electron bombardment induced conductivity and also photoconductivity, means for directing a wiring electron beam having electrons of a predetermined energy of said conductive coating so as to penetrate said coating and generate charge carriers within said first and second layers, means for establishing a field across said first and second layers such that said conductive coating is at a different potential with respect to the potential of the exposed surface of said second layer so that charge carriers generated within said first and second layers are collected by said conductive member to establish a charge pattern on the exposed surface of said second layer, and means for directing electrons at said exposed surface of said second layer to restore said surface to an equilibrium potential while simultaneously deriving a signal from said target representative of the energy of the writing beam directed thereon.

2. A storage device including a target electrode comprising a first layer of a material which exhibits the property of electron bombardment induced conductivity and generation of light in response to electron bombardment, a second layer positioned in close proximity to said first layer exhibiting the property of electron bombardment induced conductivity and photoconductivity, an electrically conductive means positioned on one side of said first and second layers, means applying a field across said first and second layers to remove charge carriers generated therein by electron bombardment induced conductivity and photoconductivity, means directing a writing electron beam onto said target to penetrate said first and second layers to generate charge carriers due to electron bombardment induced conductivity and photoconductivity and means directing a reading electron beam onto said target to modulate said reading beam in accordance with the information placed on said storage structure in response to the bombardment by said writing beam.

3. A target for an electron discharge device comprising an electrically conductive layer, a coating of a mixture of materials deposited on one surface of said conducting layer, said mixture comprising a first material which exhibits the property of electron bombardment induced conductivity and photoconductivity and a second material in said mixture exhibiting the property of electron bombardment induced conductivity and cathodoluminescence.

4. A target for an electron discharge device comprising an electrical conductive member, a first layer of a material exhibiting the property of electron bombardment induced conductivity and cathodoluminescence provided on said conductive layer, a second layer exhibiting the property of electron bombardment induced conductivity and photoconductivity and a barrier layer positioned between said first and second layers of a material which exhibits electron bombardment induced conductivity and is transparent to the radiation generated by said first layer.

5. A target electrode for a storage device comprising a first layer of a material which exhibits the property of electron bombardment induced conductivity and generation of light in response to electron bombardment, a second layer of high resistive material deposited on said first layer which exhibits the property of electron bombardment induced conductivity and photoconductivity, an electrically conductive means positioned on one side of said first and second layers, means for applying a field across said first and second layers sufficient to remove charge carriers generated within said layers due to electron bombardment induced conductivity and photoconductivity, means for directing a writing electron beam onto said target electrode of sufficient energy to penetrate said first and second layers to generate charge carriers and light therein, and means for directing a reading electron beam onto said target electrode to derive a signal from said target electrode representative of the information placed on said target electrode in response to the bombardment by said writing beam and movement of said charge carriers by said field.

6. A target for an electron discharge device comprising an electrically conductive support layer, a coating of a mixture of materials deposited on one surface of said conductive layer, said mixture comprising a first material which exhibits the property of electron bombardment induced conductivity and photoconductivity and a second material in said mixture exhibiting the property of electron bombardment induced conductivity and emission of radiation in response to electron bombardment, said first material responsive to said radiation.

7. A target for an electron discharge device comprising an electrical conductive member, a first layer of a material exhibiting the property of electron bombardment induced conductivity and cathodoluminescence and a second layer exhibiting the property of electron bombardment induced conductivity and photoconductivity and a barrier layer positioned between said first and second layers of a material which exhibits electron bombardment induced conductivity and is transparent to the radiation generated by said first layer, said second layer responsive to radiations from said first layer to induce conductivity therein.

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