

[54] STORAGE AMPLIFIER SCREEN

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313/108 R, 108 A, 108 B, 94

[56] References Cited

UNITED STATES PATENTS

2,909,692 10/1959 Cusano250/213 R
2,939,029 5/1960 Wahling.....250/213 R

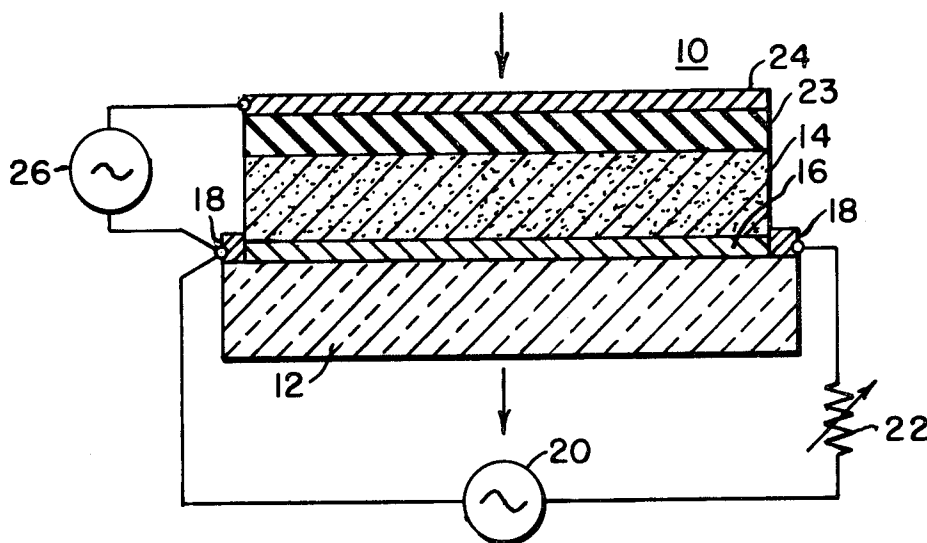
2,972,692 2/1961 Thornton.....250/213 R
3,500,101 3/1970 Burns.....250/211 R

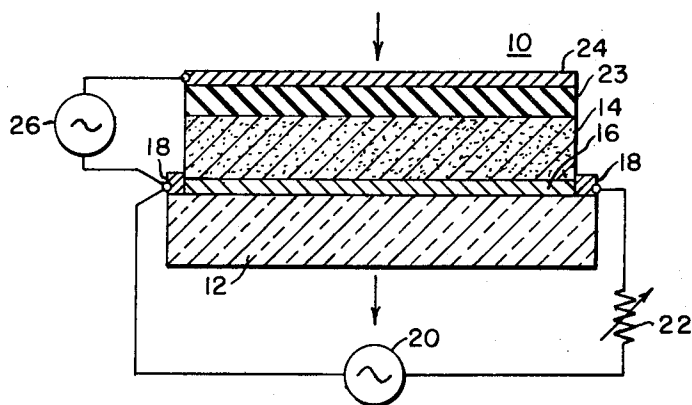
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[57] ABSTRACT

A storage amplifier screen comprising a layer of photoconductive material responsive to an input radiation and a layer of electroluminescent material emissive of an output radiation are sandwiched between two electrical conductive electrodes. The screen provides high sensitivity, resolution and gain. The photoconductive material, doped zinc oxide, provides the property of persistence of the input image under excitation for over 10 minutes after removal of input radiation. The photoconductive layer also provides the property of storage of the image for days in the absence of an electrical field.

12 Claims, 1 Drawing Figure





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STORAGE AMPLIFIER SCREEN

BACKGROUND OF THE INVENTION

This invention is generally directed to a storage amplifier screen and more particularly to a storage screen exhibiting the property of converting radiation in the X-ray region into a visible radiation.

Several constructions of solid state amplifiers and converters have been demonstrated over the last 20 years. The principal goal in most of these constructions was to build a screen with higher brightness than that of the fluoroscopic screen provided in X-ray applications to limit exposure of a patient and permit study by the doctor. Some of these constructions exhibited storage. However, the storage time was short and usually less than a minute. The image deteriorated very much in this small amount of time. These constructions were of many types and suffered from many disadvantages. They were limited in resolution, gain, sensitivity and contrast. Several of the devices were also critical in their construction.

Photographic film is presently used in medical and industrial radiography where high contrast and high resolution is required. The expense, the time delay and inconvenience resulting from the required processing of the film, are undesired features of photographic radiography. A general discussion of this background is found in an article entitled "Solid State Image Intensifiers," Radiography Amplifiers, and Infrared Converters by the inventor in the Dec. 1969 issue of Electro-Technology.

SUMMARY OF THE INVENTION

This invention is directed to a storage display panel incorporating an electroluminescent layer and a photoconductive layer sensitive to an input radiation image to provide a conductivity image corresponding to said input image. The photoconductive layer also exhibits the property of retaining this conductivity image for a substantial time after removal of the incident radiation. A suitably doped zinc oxide layer provides a good quality image for a period of time of from 10 to 100 minutes and the conductivity image may be erased by heating the storage display panel.

BRIEF DESCRIPTION OF THE DRAWING

The invention will become more readily apparent from the following exemplary description in connection with the accompanying drawings in which a schematic showing is made of a storage panel in accordance with the teachings of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring in detail to the drawing, a storage panel 10 is illustrated. The storage panel 10 may be rectangular in shape and may be 8 x 10 inches in size. The storage panel 10 is comprised of a support plate 12 of the suitable material transmissive to radiations generated by an electroluminescent layer 14. A suitable material for the plate 12 is glass or plastic. A glass sheet 12 having a thickness of about 1.5 millimeters may be utilized. An electrical conductive layer 16 is provided on one surface of the support plate 12 and is also transmissive to radiations from the electroluminescent layer 14. A

suitable material for the layer 16 is tin oxide evaporated to a thickness of about 100 nanometers and having a resistance of about 100 ohms per square. Electrical conductive bus bars 18 are provided on opposite sides of the conductive coating 16 and these bus bars 18 are of a suitable material such as copper and are connected to a potential source 20 through a variable resistance 22. The source 20 may be a AC potential source of about 50 volts to provide means of applying electrical current through the layer 16 in order to provide heat to the storage amplifier. The electroluminescent layer 14 is deposited on the conductive layer 16 and is comprised of an electroluminescent powder embedded in a high dielectric plastic material with the phosphor to dielectric ratio being approximately 3 to 1 by weight. The thickness of the layer 14 may be from about 25 to 50 micrometers. The electroluminescent material in layer 16 may be of a suitable electroluminescent phosphor such as zinc sulfide activated with copper and bromine and embedded in a high dielectric constant type plastic such as a mixture of cyanoethyl starch and cyanoethyl sucrose.

A photoconductive layer 23 is provided on the electroluminescent layer 14. The layer 23 may be prepared in the following manner: Mix with 100 grams of very pure, very fine (less than 1) micron zinc oxide powder, 25 milligrams to 1 gram with an optimum amount of 100 milligrams of reagent quality sodium sulfate (Na_2SO_4) and from 0. to 1 gram optimum 100 milligrams of reagent quality lead chloride (PbCl_2) powder. This mixture, which includes less than 2 percent by weight of sodium sulfate and lead chloride, is baked in an air atmosphere at about 1000°C for about 2 hours. This temperature may range from 900° to 1200°C. After the powder is cooled, it is placed in a blender with deionized water and blended for one minute at high speed. This mixture is then poured into a flask and the powder is settled down and the water decanted off. This process may be repeated for washing the powder. The powder is then rinsed with 2-propanol, settled, decanted and ultrasonically agitated for three minutes. The resulting powder propanol paste is then dried on a 0.8 micrometer pore size filter and then in a forced air oven at a 135°C for about 30 minutes. The powder then may be passed through a 200 mesh sieve.

The above doped zinc oxide powder is then mixed with a plastic about 100 grams of the sensitized zinc oxide powder to 3 to 30 grams of a silicone resin DC 804 purchased from Dow Corning, 25 grams of amyl alcohol and 2.5 grams of diethyl carbitol. This is ball mill mixed and is then ready to be applied to the electroluminescent layer 14. The zinc oxide silicone mixture is bladed onto the electroluminescent layer 14 to a thickness of about 200 to 400 micrometers. This coating 23 may be applied by simply utilizing a blade or a thin layer coating machine. The bladed-on layer 23 is then allowed to dry in a horizontal position. The layer 23 has a resistance of about 10^8 ohm cm.

An electrically conductive layer 24 is then evaporated onto the photoconductive layer 23. The layer 24 is transmissive to the input radiations and a suitable layer for X-rays is gold. The layer 24 also absorbs the disturbing or scattered radiation. The layer 24 is evaporated to a thickness of about 0.1 to 1 micrometer and has a resistance of about 20 ohms per square.

An AC voltage source 26 is connected between the conductive layer 16 and the layer 24 to provide a voltage of about 200 to 400 volts and of a frequency of about 60 to 1000 Hz.

In the operation of the device, the X-ray image is directed onto the storage amplifier 10 through the layer 24 and modifies the conductivity of the photoconductive layer 23 in accordance with the X-ray image input. During this phase of the operation, neither the potential source 20 nor the potential source 26 need be connected to the amplifier. The storage layer 23 exhibits the property of integration over a period of time. After the completion of the exposure by the X-rays, an increased conductivity image remains in the layer 23 corresponding to the input radiation. The potential source 26 may be applied, and an image may be viewed through the layer of 20 due to the AC potential applied across the electroluminescent layer 14 and the photoconductive layer 23. The light image will correspond to the conductivity image within the photoconductive layer 23. The image may be viewed in this manner for several minutes and for as long as a 100 minutes without a substantial degradation of the light image. It is also possible, if desired, to remove the excitation of the potential 26 and the conductivity image will be retained in the photoconductive layer 23 for a period of several days and then by application of potential by the voltage source 26 the image may be viewed again. Prior to the reuse of the screen, the image may be erased by applying the potential source 20 which provides an electrical current through the layer 16 causing the heating of the photoconductive layer 23 and thereby removing the conductivity image from the layer 23. After this erasing, the storage amplifier is ready to be utilized in the manner above. The image can also be erased by simply baking the entire panel in a furnace for 5 to 10 minutes at a temperature of about 100°C.

If desired, the device can be made more sensitive to other radiations such as visible light by the addition of an organic sensitizing dye to the zinc oxide powder. For example, by mixing rhodamine, an organic dye, to the zinc oxide powder in a proportion by weight of 1 to 2000, the amplifier may be made sensitive to the visible light input.

The required characteristics for the photoconductive layer 23 is a material that has a trap density above the Fermi level (shallow traps) higher than 10^{17} traps cm^{-3} in an energy slice kT for an energy band of several tenths of an electron volt. The materials must have a very low capture cross section of deep traps (recombination centers) or extremely short hole life time. Materials must have a high bandgap (between the valence and conduction band). In such material, the available electrons will supply a slowly decaying photoconductive current for several minutes after their radiation to the storage member is ceased. The photoconductive layer 23, after a long time in the dark or after eraser, has a very low dark current. Its shallow traps are empty and no electrons are thermally excited from the valence band to the conduction band because of the high bandgap (greater than 3 eV). Irradiation of the photoconductor excites electrons from the valence band to the conduction band. These electrons will fill up the shallow traps. The electrons in the conduction

band and in the shallow traps are in thermal equilibrium; they are changing place many times before recombination occurs (electrons extracted by the positive electrode will be replenished through the ohmic contact of the other electrode). After the excitation stops, the large number of trapped electrons will support a decaying flow of current until the traps are again emptied.

The storage amplifier described above exhibits a long storage time or persistence and decays to about one-third of maximum brightness in 5 to 50 minutes. The device also exhibits high resolution of about 6 to 10 line pairs per millimeter. The device also has a high contrast sensitivity and the device also exhibits medium high sensitivity to X-rays and very low sensitivity to visible light. The radiographic quality of the panel is 2-2T. (This means 2T holes of a 2 per cent penetrometer can be detected.) These characteristics are particularly desirable in that these storage amplifiers may be substituted for radiographic film for nondestructive X-ray testing with the advantage of immediate viewing without film processing. The device also may be erased and utilized over and over.

I claim:

1. A display storage panel for reproduction of an image of incident radiation comprising a radiation responsive layer comprising zinc oxide material containing predetermined amounts of oxygen and sodium, said radiation responsive layer exhibiting the property of producing a conductivity image corresponding to said incident radiation in response to said input radiation and persisting after removal of said input radiation, a display layer of material coupled to said radiation responsive layer and including material responsive to conductivity changes in said radiation responsive layer to display an image corresponding to said conductivity image.

2. The display storage panel of claim 1 in which said zinc oxide material additionally contains predetermined amounts of lead and chlorine.

3. The display storage panel of claim 1 in which said display layer is comprised of electroluminescent material.

4. The display storage panel of claim 1 in which a plastic material surrounds said zinc oxide material.

5. The display storage panel of claim 3 in which electrically conductive electrodes are provided for impressing an electric field across said radiation responsive layer and said delay layer.

6. The display storage panel of claim 5 in which said electric field is provided by an alternating current source.

7. The display storage panel of claim 6 in which said input radiation is in the X-ray region.

8. The display storage panel of claim 1 in which said zinc oxide material contains dye material to modify the wavelength response of said radiation responsive layer to said input radiations.

9. The display storage panel of claim 1 in which means is provided for impressing heat on said radiation responsive layer to remove said conductivity image from said radiation responsive layer.

10. The display storage panel of claim 9 in which said means for impressing heat is an electrically conductive electrode extending across said panel and supplied with electrical current to heat said electrode.

11. The display storage panel of claim 4 in which said radiation responsive layer has a thickness at least four times greater than the thickness of said display layer.

12. The display storage panel of claim 11, in which said radiation responsive layer is greater than 200 5 micrometers in thickness.

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