United States Patent

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[54] SOLID-STATE PHOTOCONDUCTOR-ELECTROLUMINESCENT IMAGE INTENSIFIER
5 Claims, 2 Drawing Figs.

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[51] Int. Cl. H01j 31/50
[50] Field of Search .... 250/213, 71 R, 83.3 R, 213 R; 313/108 R, 108 A

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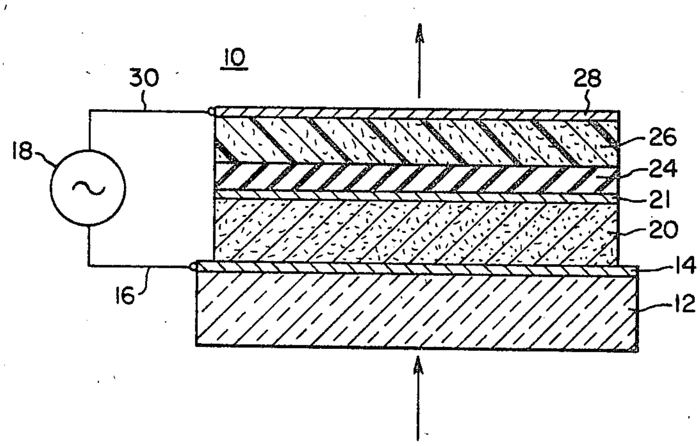
ABSTRACT: A solid-state photoconductor-electroluminescent intensifier having improved photoconductive layer construction and innerconnection with the electroluminescent layer.



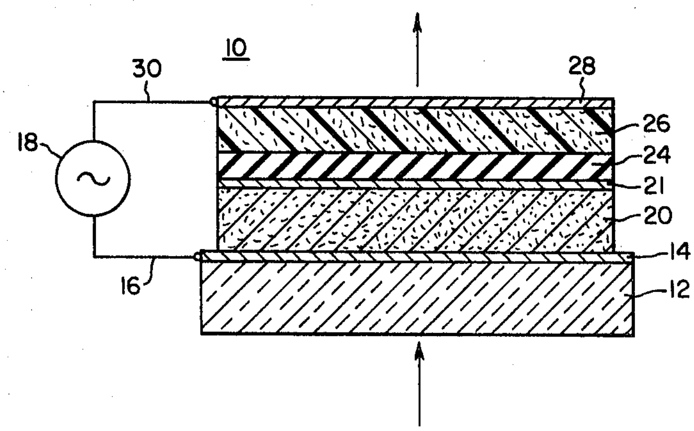


FIG. 1.

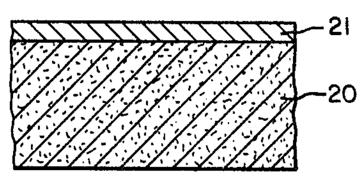


FIG. 2.

WITNESSES

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SOLID-STATE PHOTOCONDUCTOR-ELECTROLUMINESCENT IMAGE INTENSIFIER

ORIGIN OF INVENTION

The invention herein described was made in the course of or under a contract with the Department of the Navy.

BACKGROUND OF THE INVENTION

An image converter utilizing the combination of a photoconductor and electroluminescent layer structure is well known in the art and is generally described in U.S. Pat. No. 3,210,551. In spite of the great initial promise of such a combination as a light intensifier and converter, the solid-state device has not been widely used. The primary problems in the development of the device have been limitations of the materials and fabrication difficulties. The working principle of the photoconductor-electroluminescent image intensifier is basically the combination of an electroluminescent element and a photoconductive element connected in series with an alternating potential applied across the series combination. In the absence of input light to the photoconductor, the impedance of the photoconductive element is much higher than that of the electroluminescent element. The voltage across the electroluminescent cell is low and its brightness is very low. When the photoconductive element is illuminated, its resistance decreases and more voltage is applied across the electroluminescent element with the result of increased output light from the electroluminescent cell. One limitation in the design of the device is that the capacitance ratio of the electroluminescent layer to the photoconductive layer must be higher than 3 to 5, depending on the discrimination ratio of the electroluminescent cell. It has therefore been found necessary in most applications to provide a photoconductive layer of about 5 mils in thickness. These layers are commonly prepared by settling or spraying methods in which the starting material is a photoconductive powder. In some applications it is also necessary to provide an opaque layer of material between the photoconductor and the electroluminescent layer to prevent light feedback from the electroluminescent layer to the photoconductive layer. In addition, it has also been found necessary with sintered photoconductive layers to utilize a mosaic structure of gold on the photoconductive layer in order to ensure high gain within the photoconductive unit in response to light input.

The above structures have been found to severely limit the resolution and the image is grainy in appearance. It is therefore a general object of this invention to provide an improvement in the structure of the solid-state image intensifier, to improve resolution, to reduce the grainy structure of the photoconductive layer and to improve the gain of the amplifier.

SUMMARY OF THE INVENTION

This invention is related to improvements in solid-state image devices which incorporate a photoconductive element and an electroluminescent element connected in series. More particularly, this invention is directed to the improvement of the photoconductive layer and the interconnection between the photoconductive layer and the electroluminescent cell. In this specific embodiment, this is obtained by providing a sintered layer of photoconductive material having an evaporated layer of a suitable material on the surface of said photoconductor facing said electroluminescent cell. BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a sectional view of an image intensifier panel incorporating the teachings of this invention; and

FIG. 2 is an enlarged view of a portion of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring in detail to FIG. 1, an image intensifier panel portion **10** is illustrated. The panel **10** consists of a support plate **12** which is of a suitable material transmissive to the input of radiations. A suitable material for visible light is glass. The plate **12** is coated on one surface with a layer **14** of a suitable electrically conductive material such as tin oxide. The layer **14** has a thickness of about 800 angstroms and a resistance of about 100 ohms per square. The electrical conductive layer **14** is provided with a lead **16** which is in turn connected to a potential source **18**. The potential source may be an AC supply having a frequency of about 60 to 2,000 Hz. and a voltage of about 50 to 300 volts. A layer **20** of photoconductive material is deposited on the conductive coating **14**. Any suitable material sensitive to the input radiations may be utilized. Cadmium sulfide and cadmium selenide are two possible materials for image intensifier applications. One specific manufacturing technique is to provide about 100 grams of cadmium selenide powder, (electronic grade) 4 grams of dry cadmium chloride ($CdCl_2$) dissolved in 20 milliliters of de-ionized water, and 10 milligrams of copper chloride ($CuCl_2$) dissolved in 5 milliliters of de-ionized water. The cadmium selenide powder is then mixed with adequate de-ionized water to form a thick paste. The cadmium chloride solution is added and thoroughly stirred and then the copper chloride is added to the mixture and thoroughly stirred. The water is then evaporated from the mixture in a forced draft oven at 100° C. and then prebaked at about 500° C. for 1 hour. The mixture after cooling is ground and passed through a 200 mesh screen. About 20 grams of prepared powder is mixed with 50 milliliters of Xylene and ball-milled for 5 to 16 hours. The substrate glass with the conductive coating is placed in a horizontal position within a jar and the jar is filled to a height of about 5 inches above the substrate glass with 1 percent ethyl cellulose-Xylene solution. The photoconductive powder mixture is then poured into the settling jar and settled for about 1 or 2 hours. The liquid is then siphoned off and the panel is allowed to dry for several hours. The panels are then preheated slowly to about 100° C. for a half hour and then transferred to a forced air oven and baked at 135° for a half hour. After the above process, the panels are sintered by a method which involves placing the panels in a covered Pyrex dish and baking them in a furnace at about 500° C. to 520° C. for a period of about 40 minutes. The layer **20** of the sintered photoconductive material prepared by the method just described has a thickness of about 125 micrometer, as indicated in FIG. 2.

The next step in the operation is the evaporation of a semiconductive film **21** onto the sintered photoconductive layer **20**. In one specific application, cadmium selenide powder was placed in a suitable boat in a vacuum of about 10^{15} torr and heated to a temperature of 800° C. and a coating of approximately 300 manometers is evaporated onto the layer **20**. The evaporated CdSe layer **21** has an excess of cadmium and thus provides a highly doped N-type layer. Consequently, electron injection and high gain can be obtained from the photoconductive layer **20**. However, the conductivity of the semiconductive layer **21** must not be in excess of 10^{110} mho/square to prevent spreading of the image and loss of resolution.

Another suitable material that has been utilized is germanium. If the germanium evaporated layer **21** is placed on the photoconductive layer prior to sintering, an improved picture quality image may be obtained but with a lowering in sensitivity.

An opaque coating **24** is deposited on the coating **21** by evaporation and may be of a suitable material such as magnesium fluoride and indium. These materials are coevaporated to provide an opaque film having a thickness of about 1μm. This coating is more thoroughly described in the copending application Ser. No. 787,960 filed Dec. 30, 1968, entitled Opaque Insulating Film by M. A. Novice.

The next film is a layer of electroluminescent material which is illustrated as layer **26** and is a plastic embedded electroluminescent layer. The plastic material may be cyanoethyl starch and any suitable phosphor such as ZnS activated with Cu and CL. An electrical conductive light-transmissive coating **28** of a suitable electrical conductive material such as an evaporated composite film of lead-oxide/ gold (PbO/Au) having a transmission of about 65 percent and a resistance of 50 ohm/square is provided on the exposed surface of the electroluminescent layer **26**. The electrode **28** is connected by a lead **30** to the voltage source **18**.

In the operation of the device, the AC potential from the source **18** is applied across the sandwich by means of the electrodes **14** and **28**. The input radiation, such as visible light, infrared or X-rays is directed through the glass support **12** and the electrode **14** to the photoconductive layer **20**. This modifies the voltage distribution across the electroluminescent layer **26** and the photoconductive layer **20** according to the illumination pattern causing the appearance of an intensified image on the electroluminescent layer, which may be viewed through the light-transmissive electrode **28**. It is found that with the utilization of a semiconductive film **21** that the previously used gold mosaic may be dispensed with and yet still obtain an adequate ohmic contact to the photoconductive layer **20**. In addition the sensitivity of the device is found to improve and the grainy structure in this image is substantially reduced.

Various modifications may be made within the spirit of this invention.

We claim as our invention:

1. A solid-state electroluminescent display device comprising a body of semiconductive material and a layer of electroluminescent material sandwiched between two electrically conductive electrode members, said semiconductive body comprised of a first and second layer; said first layer of semiconductive material exhibiting the property of change in conductivity in response to an input radiation said first layer provided on one of said electrode members by settling and sintering and said second layer of semiconductive material evaporated onto the surface of said first layer facing said electroluminescent layer, an ohmic contact provided between said first layer and second layer, said second layer being substantially thinner than said first layer and having a lateral conductivity of less than 10^{110} mho/square.

2. The device set forth in claim **1** in which said second layer has a higher donor concentration than said first layer to provide the ohmic contact to said first layer.

3. The device set forth in claim **1** in which the thickness of said second layer is about 300 nanometers.

4. The device set forth in claim **1** in which the semiconductive material of said second layer is selected from the group of materials consisting of germanium and cadmium selenide.

5. The device set forth in claim **1** in which the semiconductive material of said first layer is selected from the group of materials consisting of cadmium sulfide and cadmium selenide.