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2,884,541

ELECTROLUMINESCENT IMAGE DEVICE

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This invention relates to electroluminescent image devices, and particularly to such devices as are designed primarily for intensifying light or light images.

This invention is directed to an improvement of electroluminescent devices of the type which comprise a first layer of electroluminescent phosphor material, a second layer of a material having a variable impedance characteristic in response to incident radiant energy (e.g. photoconductive material) on one surface of the electroluminescent layer, and a plurality of spaced apart elongated conductors, such as strips, on the other surface of the electroluminescent layer. In operation, a voltage is applied between the adjacent conductors so that with no light incident on the photoconductive layer the impedance of the photoconductive layer is high enough to limit any effective current flow between the conductors. However, when light or a light image is projected onto the photoconductive layer, the impedance of the photoconductive layer is reduced in the illuminated areas by an amount corresponding to the intensity of the incident light, so as to produce a low resistance path between adjacent conductors and thus a corresponding increase in the current flow between the conductors in the illuminated areas and through the electroluminescent layer sufficiently to cause the electroluminescent phosphor to luminesce.

Thus, any variations in intensity of the projected light, as will be present in a light image, will produce corresponding variations in the electric current flowing through the electroluminescent layer, with resulting corresponding variations in the electroluminescent light.

In the operation of such a device, the electric field extending between adjacent conductors is strongest at their adjacent edges and drops off rapidly in the direction away from the edges. This same electric field extending through the electroluminescent layer and the photoconductive layer progressively weakens in the areas away from the adjacent edges of the conductors. The result is a reduced effective area of light emission from the electroluminescent layer and a loss in sensitivity of the photoconductive layer, due to localization of the electric field, such that high light gains even with increased voltage are difficult to achieve.

Accordingly, a principal object of this invention is to improve the efficiency of electroluminescent devices of the type referred to.

Briefly, the invention consists in interposing in a device of the type described a mosaic of discrete conductive elements intermediate a photoconductive layer and electroluminescent phosphor, with the conductive elements registered with spaced-apart elongated conductors, such as strips, on the other side of the phosphor. Each conductive element and the portions of the electroluminescent phosphor and conductors registered therewith constitutes a discrete electroluminescent cell. When a potential difference is applied between adjacent conductors, the

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resultant electric field produced in adjacent electroluminescent cells is more uniform and the actual light emitting area is increased. Similarly, the electric field appearing through the photoconductive layer between the conductive elements of adjacent electroluminescent cells is increased and the sensitivity thus improved.

In the drawing:

Fig. 1 is a partial plan view with portions removed of an electroluminescent device constructed according to the invention;

Fig. 2 is a partial sectional view taken along the lines 2—2 of Fig. 1;

Fig. 3 is a partial sectional view showing a modification of the invention; and

Fig. 4 is a partial sectional view showing still another modification of the invention.

In Figs. 1 and 2 there is shown a transparent support member 10, such as a plate of glass or plastic, supporting on a surface thereof two sets of intermeshed elongated conductors 12 and 14. The conductors 12 and 14 are transparent and may comprise tin oxide, tin chloride, or any other suitable conductive material applied as very thin strips having substantial length compared to their width. Each set of conductors 12 and 14 has a common electrical connection, such as bus bars 16 and 18 respectively for making electrical connection to a voltage source 20.

A layer of electroluminescent phosphor material 22 is applied over the conductors 12 and 14. The phosphor layer 22 may comprise any suitable electroluminescent phosphor material, preferably embedded in a dielectric binding material, such as ethyl cellulose, polystyrene or an epoxy resin such as Araldite. Suitable phosphor materials are zinc sulfide activated with copper, and zinc selenide activated with manganese, for example. A thin layer of light opaque insulating material 24 is applied over the electroluminescent phosphor layer 22. The opaque layer 24 may comprise lampblack mixed with insulating material, such as ethyl cellulose. In some cases it may be preferred to omit the opaque layer, as will be explained later.

A mosaic of conductive elements 26, each of which may be rectangular, is applied on the opaque layer 24. The conductive elements 26 form rows registering with the conductors 12 and 14. Each conductive element 26 and the registering portions of the electroluminescent phosphor layer 22 and the conductors 12 or 14 constitute an elemental electroluminescent cell. The conductive elements 26 may be formed from silver paste or other metallic powder mixed in a suitable binder, for example.

A layer of photoconductive material 28 is applied in intimate contact with the mosaic elements 26 but not necessarily bonded thereto. The layer 28 may comprise any material which has a variable impedance characteristic in response to incident radiation. It may comprise a powdered layer of cadmium sulfide or cadmium selenide mixed with a dielectric binder such as the binders used for the electroluminescent layer 22. These and other photoconductive powders are disclosed in copending application of Charles J. Busanovich and Soren M. Thomsen, Serial No. 472,354, filed December 1, 1954, now U.S. Patent Number 2,876,202. When a powder layer is used, it may be applied directly by spraying over the mosaic elements 26. However, it is preferred to use a sintered photoconductive layer, such as is disclosed in copending application of Soren M. Thomsen, Serial No. 473,001, filed December 3, 1954, now U.S. Patent No. 2,765,385. The sintered layer may comprise suitably activated cadmium sulfide or cadmium selenide, for example. Such a

sintered layer has high sensitivity and relatively high speed of response. When a sintered photoconductive layer is used, it may be applied to a separate transparent support 30, such as a plate of glass or plastic. Thereafter the two plates 10 and 30 may be brought together to make pressing contact between the photoconductive layer 28 and conductive elements 26. To this end, before the assemblies on the plates 10 and 30 are joined, the conductive elements 26 may be applied rather thick and then machined down to a uniform thickness. This will assure intimate contact between the photoconductive layer 28 and the conductive elements 26 when the two plates 10 and 30 are joined together.

As an example of the physical dimensions used, the elongated conductors 12 and 14 may be strips .040 inch wide and spaced .020 inch apart. The electroluminescent layer 22 and opaque layer 24 may each be .001 inch thick. The photoconductive layer 28 may be a sintered layer of cadmium selenide of a few microns thickness. If a photoconductive powder layer is used it may be .005 inch thick. The conductive elements 26 may be rectangular, .040 inch long in the direction perpendicular to the elongated conductors 12 and 14, .020 inch wide, and spaced .020 inch apart in the direction parallel to the elongated conductors 12 and 14.

In operation, the source voltage 20 is preferably alternating current of several hundred cycles per second frequency and of the order of five or six hundred volts. The source 20 establishes a potential difference between adjacent conductors 12 and 14. This causes an electric field to be established between the conductors. Referring to Fig. 2, consider one pair of adjacent conductors 12 and 14, and one pair of adjacent conductive elements 26, that is, a pair of conductive elements lying in adjacent rows. These two conductive elements 26, together with the registering portions of the conductors 12 and 14 and the portions of the electroluminescent layer 22 therebetween, constitute two elemental electroluminescent cells. The electric field extends through one elemental electroluminescent cell, then across that portion of the photoconductive layer 28 between the adjacent conductive elements 26, and then through the other elemental electroluminescent cell.

In the absence of light on the elemental area of the photoconductive layer 28 extending between the pair of adjacent conductive elements 26, the impedance of the photoconductive layer 28 will be substantially higher than the impedance of each of the electroluminescent cells. This may be effected by making the thickness of the electroluminescent layer 22 of each elemental cell small as compared to the width of photoconductive material between adjacent conductive elements 26. Such relationship exists in the example cited above. Under these circumstances, the electric field appearing across each elemental electroluminescent cell, and the resulting electric current flow therethrough will be too low to cause electroluminescence.

With light incident on the elemental area of the photoconductive layer 28, the impedance of the photoconductive layer will be reduced in that area to such an extent that the increased electric field across each elemental electroluminescent cell, and the increased electric current therethrough, will be sufficient to produce electroluminescence. Light gain is achieved by virtue of the power supplied by the voltage source. Inasmuch as the current through an electroluminescent cell is a function of the intensity of the incident light, it is possible to project a light image L_1 on the photoconductive layer 28 and produce an amplified light image L_2 from the electroluminescent layer 22.

The presence of the mosaic of conductive elements 26, in accordance with the invention, provides discrete elemental electroluminescent cells and direct photoconductive paths between each cell. In this way, a more uniform electric field is produced through each elemental

electroluminescent cell rather than concentrations of electric field appearing at the edges of the conductive strips, with the result that a greater area of light emission is obtained from the phosphor. Similarly, a more uniform electric field is produced across the photoconductive layer, with resulting improvement in photosensitivity.

The function of the opaque layer 24 is to prevent light feedback from the electroluminescent layer 22 to the photoconductive layer 28. In cases where light feedback is desired, for example for the purpose of storing a visible image after the incident image has been removed, the opaque layer 24 may be omitted and the conductive elements 26 laid down directly on the electroluminescent phosphor layer 22.

In the modification shown in Fig. 3, each conductive element 32 is provided with an embossment 34 and only the embossments 34 are in contact with the photoconductive layer 28, otherwise the structure of Fig. 3 is like that of Figs. 1 and 2, like numerals identifying like elements. The embossments 34 may be formed as ribs, or they may be bead-like. The embossments 34 may be formed by machining operations performed on the elements 32. Alternatively, the elements 32 may be machined flat and then the embossments 34 may be laid down on the machined surface by silk screening techniques, for example. The embossments 34 provide a longer photoconductive path between the conductive elements 26 and hence a greater useful area of photoconductor. This permits more effective use of the incident light falling on the device and therefore increases its sensitivity. The operation is similar to the device of Figs. 1 and 2.

In the modification shown in Fig. 4, the electroluminescent material and opaque material are laid down in strips 36 and 38 respectively in registry with the elongated conductors 12 and 14. In this case, the conductive elements 26 are preferably formed without embossments. By means of this construction, the underside of the photoconductive layer 28 is exposed through the glass plate 30 so that an incident light image L_3 may be projected from the opposite side shown in Figs. 1 and 2. In this way, the projected image L_3 and the output image L_4 are on the same side. The opaque strips 38 may be omitted if the conductive elements 26 are made thick enough to be opaque by themselves. In this modification, light feedback can occur only inefficiently by reflection from the glass plate 10.

By means of the invention, then, electric fields of greater uniformity are produced in the electroluminescent cells and the associated photoconductive areas. The beneficial results thereby produced are increased light emission area and improved photosensitivity.

What is claimed is:

1. An electroluminescent image device comprising an array of spaced apart elongated conductors arranged side by side, adjacent ones of said conductors being electrically insulated from each other, electroluminescent phosphor material on each of said conductors on the same side of said array, a mosaic of mutually insulated conductive elements adjacent to said phosphor material, each of said conductive elements being registered with a conductor to form an electroluminescent cell with the phosphor therebetween, photoconductive material on said mosaic and contacting each of said conductive elements and bridging the gaps therebetween, and lead means connected to said conductors for applying a potential difference between adjacent conductors.

2. The invention according to claim 1 wherein said phosphor material comprises strips registered with said conductors.

3. An electroluminescent image device comprising a transparent support plate, two electrically insulated sets of intermeshed transparent conductive strips on said support plate, a layer of electroluminescent phosphor material overlying said strips, a second transparent support

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plate bearing on a surface thereof a sintered photoconductive layer, and means maintaining said two layers in close-spaced relationship, said means including a mosaic of mutually insulated conductive elements contacting said photo-conductive layer and registered with said strips.

4. The invention according to claim 3 wherein each of said elements includes an embossment in contact with said photoconductive layer.

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