Sept. 19, 1961 R. M. RULON 3,001,078

LIGHT AMPLIFICATION AND STORAGE DEVICE

Filed April 1, 1957

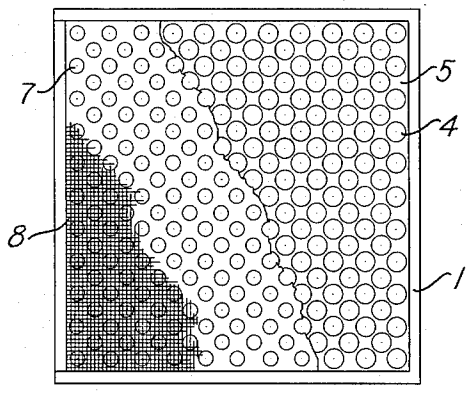


Fig. 1

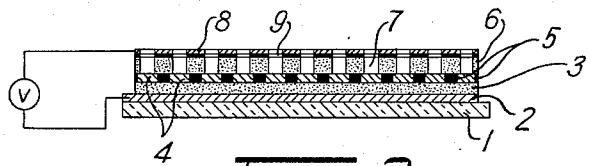


Fig. 2

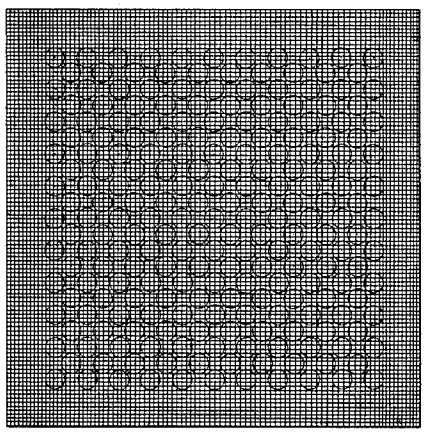


Fig. 3

INVENTOR.
RICHARD M. RULON

BY Lawrence Brown,
ATTORNEY

United States Patent Office 3,001,078 Patented Sept. 19, 1961

3,001,078

LIGHT AMPLIFICATION AND STORAGE DEVICE

Richard M. Rulon, Hamilton, Mass., assignor, by mesne assignments, to Sylvania Electric Products Inc., Wilmington, Del., a corporation of Delaware

Filed Apr. 1, 1957, Ser. No. 649,876
3 Claims. (Cl. 250—213)

This invention relates to photoconductors, and especially to methods and devices in which photoconductors are used in combination with electroluminescent devices in order to obtain amplification of light or of other radiation. The expression photoconductor, or photoconductive material, is here used as meaning a substance whose electrical impedance (that is, its resistance or reactance, or both) changes with the incident light falling upon it. In particular, the invention relates to a device for amplifying the brightness of an optical or electronic image, or for acting as a solid state storage device for use as a read-out for computers, data-processing equipment and the like.

Lighting-amplifying devices utilizing a layer of photoconductive material in series electrically with an electroluminescent layer are already known. In such prior devices the incident light did not generally penetrate the entire photoconductive layer and hence the change in impedance due to the photoconductivity was limited. Photoconductivity being more pronounced as a surface effect, the main mass of the layer remained largely unchanged in its impedance.

That difficulty can be overcome by making the photoconductive layer foraminous, that is, having numerous holes into which light passes to be reflected back and forth until absorbed. Preferably, the holes extends entirely through the layer, from one side to the other, with an electrical connection on each side. There is thus a continuous surface path between the electrodes, and the conductivity of the inside surface of the holes, and hence of the entire path from one side of the layer to the other, is directly affected by the incident light.

When a photoconductive layer is used in series with an electroluminescent layer, light amplification can be obtained, because a small amount of light incident on the photoconductive surface can, by changing the impedance of the latter, control the emission of a larger amount of light from the electroluminescent layer.

The light from the electroluminescent layer itself may feed back onto the photoconductive layer and thereby affect its operation. If the light from the electroluminescent layer is prevented from reaching the photoconductive layer, for example by the interposition of an opaque screen between the two, then electroluminescence will occur while the photoconductive surface is irradiated by incident light, but will rapidly decrease upon the cessation of the irradiation as the photoconductivity decays.

If, however, sufficient light from the electroluminescent layer is allowed to reach the photoconductive layer, then the electroluminescence, once started, will continue until the voltage is removed from the device, or until the luminescence is electrically quenched in some other manner, the electroluminescent light acting to maintain the photoconductive layer in a low impedance state.

On the other hand, if the amount of light reaching the photoconductor from the electroluminescent layer is too small to maintain a self-sustaining condition of constant brightness in the absence of incident light, it can nonetheless slow the rate at which the voltage across the layer decreases from its value in the presence of incident light to its value in the absence of said light, and thus slow the decay of the luminescence after such exposure.

Under such a condition, the time during which the

device will continue to emit light, that is the storage time, can be varied from a few microseconds to a period of days, by varying the voltage applied to the device, or by varying the intensity of the incident or triggering light.

The storage effect is useful in computer circuits, read-out circuits and the like, and also because increasing the duration of the light emission increases the total light output for a given triggering impulse.

In order to facilitate the use of my device as a light amplifier, a small conducting disc can be used on the electroluminescent layer at the "bottom" of each hole, the word "bottom" being here used merely as meaning the part of the hole nearest the electroluminescent layer. The disc can be of slightly larger diameter than the inside of the hole, in order to insure good contact with the photoconductive material. Thus when incident light falls on the inside surface of one of the holes, the impedance in series with the disc will be lowered, and the electroluminescent layer will emit light from a region in register with the hole, that is, with the conductive disc.

Since any light from the electroluminescent layer which falls on the bottom of the photoconductive layer will make the latter photoconductive on its bottom surface, that is on the surface nearest the electroluminescent material, there will be some cross-conduction between one conductive disc and another, which is undesirable if a sharp image is to be produced. Moreover, even in the absence of such stray photoconduction, the light from the electroluminescent layer can produce halation effects by internal reflections.

I find that such stray conductivity and halation can be reduced or eliminated by the use of a black insulating coating over the area on the electroluminescent layer not covered by the conducting discs. I have found that an opaque coating of a glaze or enamel, preferably black, is very effective.

Such a coating is superior to a black coating of graphite, which while opaque, has appreciable direct conductivity, and which also has the disadvantage of requiring a non-oxidizing or reducing atmosphere during the sintering of the photoconductive material which is placed over it. The use of the enamel glaze, on the other hand, will permit such sintering in ordinary air.

Other objects, advantages and features of the invention will be understood from the following specification taken in connection with the accompanying drawings in which:

FIGURE 1 is a plan view of one embodiment of the invention;

FIGURE 2 is a profile cross-section of the same device; and

FIGURE 3 shows the device in various stages of manufacture.

In FIGURES 1 and 2, the glass base plate **1** carries a surface layer of a transparent conductive coating **2**, which may be one of the type well-known in the art such as the stannous chloride coating shown in the United States Patent 2,566,349, issued September 4, 1951, to Eric L. Mager. Over the coating **2** is an electroluminescent layer **3**, which can consist of an electroluminescent phosphor embedded in a solid dielectric material. The phosphor may be of a type well-known in the art for example, as shown in United States Patent 2,774,739, issued December 19, 1956, to Keith H. Butler, and the dielectric coating in which it is embedded can be, for example, of the ceramic or glass type shown in copending application Serial No. 365,617, filed July 2, 1953, by Richard M. Rulon.

A series of spaced conducting discs **4** is placed over the electroluminescent layer **3**, and an opaque coating **5**, which

according to my invention is of black enamel, covers the area between the discs 4.

Over conducting discs 4 and the opaque layer is a layer 6 of photoconductive material containing numerous cylindrical holes 7, and at the bottom of each hole is a circular conducting disc 4. The diameter of the disc 4 is slightly larger than the diameter of the hole 7 in order to make good contact at the bottom of the hole 7 with the photoconductive material 6. The latter may be copper-activated cadmium sulfide, which is well-known material of that type, or may be of some other suitable material. The discs 4 may be formed of transparent conductive coating, such as the material used in coating 2, or if the light transmission is not desired, it may be a coating of metal and, if no interaction between the light and the electroluminescent layer 3 and the photoconductive layer 6 is desired, may even be opaque.

The opaque coating 5, which according to the invention can be of black enamel, for example, covers the area between the discs 4, in order to prevent electrical connection of one dot to another by photoconductivity produced on the bottom of the photoconductive layer 6 by light from the electroluminescent layer 3, and also to reduce halation due to internal reflections in the electroluminescent layer of the photoconductive layer 6.

A device according to the invention can be made by beginning with a glass plate 1 coated with a transparent conductive coating 2 of stannous chloride or the like, and applying to it an electroluminescent layer 3 of phosphor particles embedded in a ceramic dielectric.

The phosphor-dielectric layer 3 shown in FIGURE 2 can be applied, for example, as in my copending application Serial No. 365,617, filed July 2, 1953, now abandoned, that is by sifting a mixture of about, by weight, 28% phosphor particles and 72% glass frit of a composition described in said application, onto the conductive coating 2 and heating to a temperature of about 700° C. for about six minutes. The heating can be done in an oven, and immediately on removing the piece therefrom, while the coating 3 is still hot at between about 600° C. and about 700° C., the electroluminescent layer 3 is sprayed with a solution of stannic chloride in mixed solvents, in the proportion of about 1 gram of $SnCl_4$, $.5H_2O$, 0.5 cc. of formaldehyde solution (37% HCHO in water) and 0.8 cc. of ethyl alcohol (acetone-denatured).

The transparent conductive coating can then be broken up into separated conducting discs 4 by the method shown in copending application Serial No. 631,131, filed concurrently herewith by Frederic Koury. Alternatively, the coating solution can be sprayed onto the layer 3 through a screen of metal or other suitable material, the screen having holes therein in alignment with the position which the conducting discs are to occupy.

The glass base plate 1 can be of any convenient size, for example, 10 inches by 10 inches, with a thickness sufficient for mechanical strength, for example, about one-eighth inch, although a thickness as small as 0.06 inch has been used. The thickness of the conductive coating 2 is difficult to measure, because of its extreme thinness, but will be determined by conditions of application. It will generally be less than 0.001 inch, and I have used a thickness sufficient to give a resistance of 100 ohms per square, that is a resistance of 100 ohms measured between two opposite sides of a square, one of whose surfaces is coated with the material. Since the length and width of the resistive path will be the same for a coated square, the resistance will be the same for all squares and is used as a standard unit.

An electroluminescent layer 3 of a thickness of about 0.0025 inch has been used, although the thickness is not critical, and will vary with the voltage to be applied.

The layer 5 of black enamel can be of 4 to 6 mils (thousandths of an inch) thickness. The enamel layer 5 will generally have a thickness greater than that of the conductive discs, but the photoconductive layer 6 will

accommodate itself to the difference in thickness of the components of the composite underlying layer 4, 5. A photoconductive layer of thickness of about 6 to 8 mils has been used, with a diameter of 0.040 inch or 0.017 inch for the holes, the discs having a diameter, respectively, of 0.046 inch or 0.023 inch, in order to be slightly larger than the holes. A hole diameter of 0.017 inch is about right to produce a picture of about the same structure as the present television screen.

The wire screen used is about 400 mesh standard, of nickel wire, and has a light transmission of 80%.

The voltage used across a device of the foregoing dimensions was 300 to 500 volts, and the amplification ratio was 60 to 1.

The foregoing dimensions can be varied widely and are not critical, being given merely as illustrative examples.

The area between the discs or dots 4 is shown coated according to my invention with an opaque coating 5, which can be a black enamel or other suitable material applied through a suitable silk screen as shown in FIG. 3, the screen masking but exposing the surface between the dots, in accordance with the usual silk screen techniques.

A coating of photoconductive material, for example, of copper-activated cadmium sulfide is applied over the dots 4 and the opaque coating 5. The photoconductive powder can be suspended in a solution of ethyl cellulose. For example, about 6% by dry weight of N–200 ethyl cellulose can be dissolved in a solvent composed of 9.9% by weight dibutyl phthalate, 80.5% xylol and 4% butanol (butyl alcohol). "N–200" ethyl cellulose is a type having a viscosity of 200 centipoises per second in standard solution, and having an ethoxy content between 46.8% and 48.5%. About 10 cc. of the above solution is diluted with about 90 cc. of xylol, and 20 grams of copper-activated cadmium sulfide is added per 100 cc. of the solution.

After application of the suspension, it is dried, that is the xylol is evaporated, and a series of holes is made in the layer, each hole being in register with, and preferably of slightly smaller diameter than, one of the conductive discs 4. The holes can be punched through the layer 6 one by one with a needle, if desired, or they can be pressed out by a roller having a series of pins arranged to come in register with conductive dots 4, as shown in copending application Serial No. 631,131 of Fred Koury.

The dots 4 can also be applied in another manner, that is by silk screen techniques, also as described in said Koury application.

A thin wire mesh 8 is then coated with a layer 9 of silver paint of the air-drying type and pressed over the photoconductive layer 6, the silver paint acting as a conductive cement to bind the mesh 8 to layer 6. The mesh 8 can have a transmission of 80% or more so that it will not greatly reduce the amount of light entering the holes 7. A profile section of the completed device is shown in FIG. 2, with a plan view, with the wire mesh 8 broken away for clarity except at one corner, as shown in FIG. 1.

In operation a voltage V is connected between electrodes 2 and 8, as indicated in FIG. 2. The voltage is insufficient to produce appreciable luminescence when the photoconductive layer 6 is in the dark (or at a desired ambient background level of illumination), yet sufficient to produce luminescence when a predetermined intensity of light falls on the photoconductive layer 6.

An image can be focussed on the top of the device, so that light from it enters the holes, and the image will appear in amplified form on the electroluminescent layer 3, which can be viewed from the bottom through the glass plate 1. Ordinarily, the device will be used vertically, rather than horizontally as shown in the FIG. 2. Then light can fall on the photoconductive material 6 on one side and appear in amplified form in electroluminescent layer 3 on the other side.

What I claim is:

1. An information-displaying device comprising an extended transparent conductive layer, an electrolumines-

cent layer thereover, a series of separated transparent conductive areas over said electroluminescent layer, a layer of opaque insulating glaze covering the area between said separated transparent conductive areas, a foraminous photoconductive layer thereover having holes in register with said separated conductive areas, at least some of the separated conductive areas being in electrical contact with the photoconductive material around the surface of the holes, and a light-transmissive electrode connected to the outer surface of said photoconductive layer.

2. An information-displaying device comprising an extended transparent conductive layer, a layer of electroluminescent phosphor in a ceramic dielectric material thereover, a series of separated conductive areas over an opaque insulating enamel covering the area between said separated conductive areas, a foraminous photoconductive layer thereover having holes in register with said

separated conductive areas, at least some of the separated conductive areas being in electrical contact with the photoconductive material around the surface of the holes, and an electrode connected to the outer surface of said photoconductive layer.

3. An information-displaying device comprising an electroluminescent layer, a series of separated conductive areas thereover, an opaque insulating glaze covering the area between said separated conductive areas, and a foraminous photoconductive layer thereover having holes in register with said separated conductive areas.

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