

March 14, 1961

E. E. LOEBNER ET AL

2,975,291

ELECTROLUMINESCENT STORAGE DEVICE

Filed Oct. 17, 1957

Fig. 1.

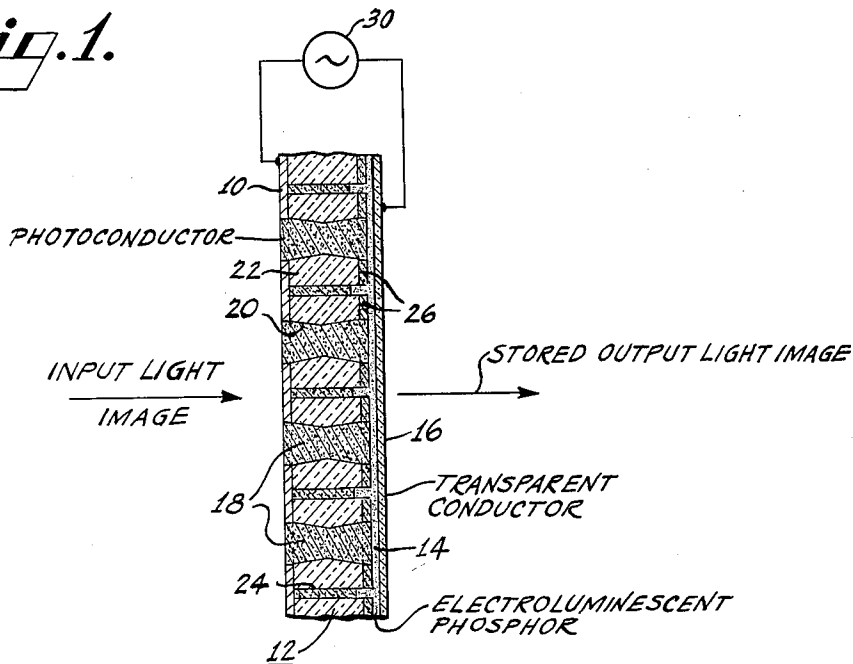
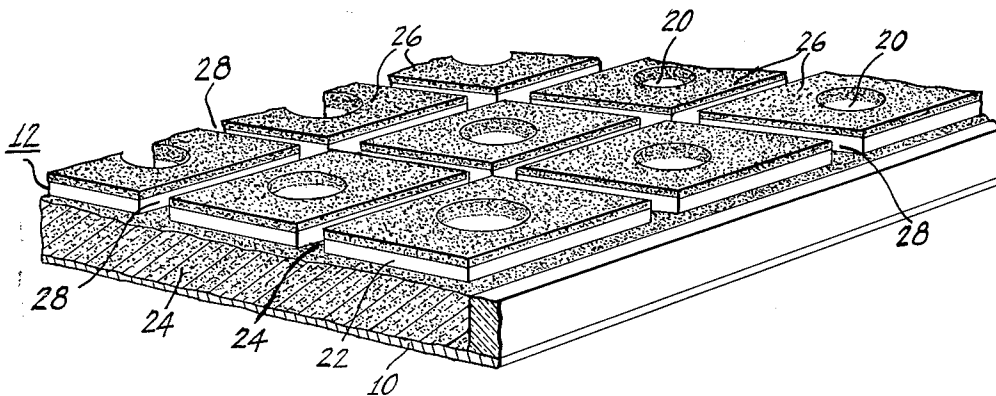


Fig. 2.



INVENTORS

EGON E. LOEBNER,
HARVEY O. HOOK &
DONALD C. DARLING

By *William A. Balesch*
ATTORNEY

1

2,975,291

ELECTROLUMINESCENT STORAGE DEVICE

Egon E. Loebner and Harvey O. Hook, Princeton, N.J.,
and Donald E. Darling, Levittown, Pa., assignors to
Radio Corporation of America, a corporation of Dela-
ware

Filed Oct. 17, 1957, Ser. No. 690,814

9 Claims. (Cl. 250-213)

This invention relates to electroluminescent devices and particularly to solid state devices designed to amplify and store radiation images, such as light images.

Solid state light amplifying and storage devices are known which comprise layers of photoconductive and electroluminescent phosphor material sandwiched between two transparent sheet electrodes. When an alternating voltage is applied to the electrodes, the two layers function as a voltage divider. Without illumination or irradiation of the photoconductive layer, the division of voltage is such that by far the greater portion appears across the photoconductive layer while the electroluminescent layer receives only a small voltage which is insufficient to cause appreciable light emission therefrom. In the presence of an incident image, such as light or X-rays, for instance, the impedance of the photoconductive layer lowers, area by area, in accordance with the radiation intensity variations in the image so that correspondingly greater voltage appears, area by area, across the electroluminescent layer. These voltage variations result in variations in light emission from the electroluminescent layer which, for a relatively wide range of incident radiation intensities, correspond to but are greater than the variations in the incoming image. The image is thus intensified.

Such a device can store an image indefinitely if a sufficient amount of the electroluminescent light is made to feed back to the photoconductive layer to keep it excited. Modified structures have also been designed specifically for storage purposes. However, most of the prior art structures do not have high storage efficiency, or lack fine definition, or are difficult to fabricate.

It is therefore a primary object of this invention to provide an improved structure, for use in a storage light amplifier, which is easily fabricated.

Another object is to provide a storage light amplifier of very fine definition and high feedback efficiency.

The above and other objects are achieved, in accordance with this invention, by providing a plate of insulating material formed with laterally spaced transparent portions integrally surrounded by opaque portions. The transparent portions are provided with apertures extending through the plate and containing bodies of photoconductive material. The bodies are respectively connected electrically to electroluminescent phosphor capacitor areas disposed adjacent to one side of the plate. Each transparent portion of the plate serves as a light duct for the illumination of the photoconductive body therein both by incident light and by light fed back from the electroluminescent area registered therewith. The opaque portions serve to absorb or reflect sufficient feedback light to prevent the undesirable triggering of neighboring image elements into storage and thus cause a smearing and spreading of the image. A mosaic of mutually isolated transparent conductive areas is arranged as interlayer electrodes between the transparent portions and the phosphor areas in such fashion as to permit the

2

electroluminescent light emission to be directed most efficiently through the transparent light ducts and onto the surfaces of the photoconductive bodies.

In the drawings:

Fig. 1 is a fragmentary sectional view of a storage light amplifier according to the invention; and

Fig. 2 is a fragmentary perspective view showing a portion of the device of Fig. 1 enlarged and in greater detail.

Referring to Fig. 1, the storage light amplifier panel comprises a number of layers which include a first conductive coating 10, an apertured insulating plate 12, a mosaic of conductive patches 26, an electroluminescent phosphor layer 14, and a second conductive coating 16, in that order. Bodies 18 of photoconductive material are contained in the apertures of openings 20 of the plate 12. The first conductive coating 10 is transparent to the input radiations, and the second conductive coating 16 is transparent to the output radiations.

As shown in greater detail in Fig. 2, the apertured plate 12, preferably of glass, is made up of a great many transparent volumes or light ducts 22 optically separated from one another by a network of relatively narrow opaque portions of light baffles 24. The plate 12 is a unitary structure, with the opaque portions 24 preferably being formed by darkening the original glass of which the plate 12 is composed. This process is described in greater detail later. The apertures 20 extend through the light ducts 22 from side to side of the plate 12. One side of the plate 12 is covered with the continuous transparent conductive coating 10, such as a thin film of tin oxide, gold, or aluminum. The coating 10 extends a slight distance into the apertures 20 to form a narrow conductive band on the inner wall of each aperture. Alternatively the photoconductor body may extend a slight distance outward and beyond the apertures to provide a sufficiently large contact area between the photoconductor and the coating 10. The other side of the plate 12 is coated with the mosaic of mutually insulated conductive patches 26, which are transparent to the feedback radiation. The patches 26 coat the top surfaces of the light ducts 22 and, like the coating 10, extend into the apertures 20 to form narrow conductive bands or they overlap somewhat the photoconductive body filling the apertures. In one particular method of laying down this mosaic, a network of grooves 28 is first etched into the glass and the grooves are filled with a substance which serves as a mask. The transparent conductive material is then produced on the masked plate, by spraying or otherwise, after which the masking substance is removed from the plate, leaving only the patches 26 coated on the surface of the plate 12.

The apertures 20 are filled with the bodies or plugs 18 of photoconductive material, such as cadmium sulfide or cadmium selenide crystalline powder. The powder may be applied dry or it may be mixed with a suitable dielectric binder such as ethyl cellulose or an epoxy resin. The ends of the plugs 18 make good conductive contact with the conductive coatings 10 and patches 26.

The layer 14 of electroluminescent phosphor is applied over the patches 26, and the phosphor layer 14 in turn is coated with transparent conductive material, such as a thin film of gold, forming the second conductive coating 16. The electroluminescent phosphor may fill in the grooves 28. Alternatively, the grooves may first be filled in with inert material, such as a resin, which is insulating and preferably opaque, and the electroluminescent phosphor may be subsequently applied. Electroluminescent phosphor materials are well known, and in general a material is chosen which closely matches the spectral response of the photoconductive material of the

plugs 18. Photoconductive cadmium sulfide, copper and chlorine activated, has a maximum green to red response, so that a green emitting phosphor, such as copper and aluminum activated zinc sulfide can be used with that material. The electroluminescent material is preferably mixed with a transparent dielectric binder material such as ethyl cellulose or an epoxy resin.

In operation, a source 30 of alternating voltage, such as, for example, 800 volts at 200 cycles per second frequency, is connected to the conductive coatings 10 and 16 which serve as external electrodes. In the absence of an input image on the light amplifier, most of the electric field is developed across the photoconductive plugs 18 and only a small threshold field appears across the phosphor layer 14, as is well known. When a light or radiation image is projected on the panel from either side thereof, the incoming light rays irradiate the sides of the photoconductive plugs 18, rendering the surfaces more conductive so that a greater field is built up across the adjacent portion of phosphor layer 14, whereupon the latter electroluminesces. In the areas of the panel where the incoming light is relatively intense, the plugs 18 become more conducting and there is a greater field built up across the phosphor areas adjacent thereto, so that the light emission from these phosphor areas is relatively high. In the darker areas, the plugs 18 are less conductive, the electric field across the phosphor areas is less, and the light emission is less. In this way, a mosaic of variable intensity areas of a light image is produced and amplified element by element.

The transparent conductive patches 26 of the mosaic serve to spread the currents uniformly over the adjacent areas of the phosphor layer 14 covered thereby. Furthermore, because of their location on the light ducts 22, they tend to direct back into the light ducts some of the electroluminescent light so as to establish feedback and light storage.

It has been shown that it is possible to adjust operating conditions, i.e., voltage and frequency of the power source, of a single optical positive feedback light intensifier cell so that it may have two stable operating states, one which is light emitting and the other which is essentially non-light-emitting. The ability to store indefinitely either of the two states gives rise to the term "storage light amplifier". In an image intensifying panel some light unavoidably seeps through, or cross-feeds, to "off" cells. Indefinite image storage is achieved when the intensity of this cross-feed light is kept below a certain trigger threshold of the exposed "off" cells. Above this threshold, image storage time is finite, and the speed of spreading is related to the amount of light exposure of the off-cell photoconductor.

The width of the light ducts 22 is made rather large compared to the widths both of the photoconductive plugs 18 and the light baffles 24, so that a substantial amount of light, either input or feedback, or both, can illuminate the photoconductive plugs 18. The light baffles 24 form compartments surrounding each light duct 22 and plug 18 so as to confine the light within each compartment. In this way, cross-illumination between adjacent elements and spreading of the stored light pattern is prevented.

More than one photoconductive plug may be disposed within the confines of each light baffle. For instance, it may be desired to locate a trio of such plugs, each responsive to different color light, e.g. red, green and blue, with a single baffle, with each plug being responsive to feedback light from a corresponding one of three different color emitting electroluminescent phosphor elements.

It is pointed out that the terms "transparent" and "opaque" as applied to the light ducts 22 and baffles 24 are used in a relative sense with reference to the feedback light and photoconductor sensitivity. Since, it is only the feedback light which is involved in storage op-

eration, and the feedback light may be a different color than the input light, the light baffles need only be sufficiently opaque to the feedback light and then only to that feedback light to which the photoconductor is resistive to prevent triggering of normally dark photoconductive plugs.

To fabricate the plate 12 several known techniques can be used. Thus, it is well known that certain materials like alkali halides are transparent to visible radiation when in a virgin state, but discolor and become non-transmitting in a number of wavelength ranges when exposed to X-ray or similar radiation. An opaque network is obtained in a plate of alkali halide material, such as potassium chloride or potassium fluoride, by bringing it in contact with a mask consisting of a network of X-ray transparent, i.e. low atomic number, material such as lithium, boron or graphite, filled with X-ray opaque, i.e. high atomic number, material such as lead. The alkali halide plate is then exposed to preferably collimated X-radiation through the X-ray mask. Such collimated radiation can be simulated by scanning the plate with a finite X-ray source, however, keeping satisfactory separation between source and mask and providing a suitable thickness of the mask. Instead of a conventional X-ray source, which has to be scanned, a gamma-ray emitting sheet of radio-active material can be used to expose the pattern through the above described mask.

The apertures can be obtained either by ultra-sonic machining, other physical machining, or by physico-chemical means described below. Thus, radiation from a heat lamp is allowed to fall through a focused projection system onto the glass plate, thereby producing a heat image of the desired pattern on the plate. A suitable solvent is applied to the plate, the temperature of the solvent being kept well below that at which rapid dissolving action takes place. However, at the focused heat image areas the temperature rises well above the dissolving threshold. Thus, the differential dissolving rate between the heated and cooled parts of the solvent and the plate will result in the production of the desired apertures. It should be pointed out that the formation of the apertures be preferably done before the formation of the opaque network to avoid bleaching of the opaque network by the application of heat.

In another process which utilizes photographically sensitive glass known as Fotoform glass, the Fotoform glass is exposed to ultra-violet light first through a photographic master, with clear areas in the master corresponding to the desired positions of the apertures. These areas are then developed by heating the structure to a suitable temperature, about 450° C. until the aperture areas become opalescent. One side of the glass is then ground and polished to provide a suitable surface for a second exposure, this time to the light baffle pattern. To this end, a second photographic master, with clear areas corresponding to the desired opaque areas in the glass, is registered with the previously developed aperture pattern on the glass, and a suitable exposure to ultra-violet light is made. The aperture pattern is then etched through with hydrofluoric acid, the exposed areas being more soluble in the acid than the clear areas. Next, the baffle pattern is developed by heating the plate to about 550° C. although higher temperatures up to 650° C. may be used. The structure is then ground to size and polished on both sides. The baffles are then etched on one side of the plate with hydrofluoric acid to obtain grooves. The grooves and apertures are then filled with a suitable masking material, such as Alundum, and both sides of the structure coated with a transparent conductor. The masking material is then removed, leaving the mosaic of conductive patches.

It is thus apparent by means of the invention, a storage light amplifier of simple construction and having fine definition and high feedback efficiency is provided.

What is claimed is:

1. A light-responsive structure for use in a storage light amplifier comprising a plate of glass of substantial thickness which has integrally formed therein a network of opaque portions dividing said plate into a multiplicity of optically separated transparent portions, each of said transparent portions having an opening therethrough, and at least one solid photoconductive body in each of said openings.
2. A structure comprising a plate of solid insulating material formed with an array of laterally spaced transparent portions each integrally surrounded by an opaque portion, each of said transparent portions having an opening extending therethrough and a solid photoconductive body in each of said openings.
3. A structure comprising a plate of solid insulating material formed with an array of laterally spaced transparent portions each integrally surrounded by an opaque portion, each of said transparent portions having an opening extending therethrough and a solid photoconductive body in each of said openings, and a layer of conducting material on one side of said plate registered with each of said transparent portions and connected to each of said photoconductive bodies.
4. An electroluminescent device comprising a plate of solid insulating material formed with an array of laterally spaced transparent portions each integrally surrounded by an opaque portion, a layer of electroluminescent phosphor adjacent to one side of said plate and comprising elemental areas exposed to the other side of said plate through said transparent portions, and solid photoconductive areas supported by said plate so that each photoconductive area is exposed to a corresponding one of said phosphor areas through one of said transparent portions but is optically shielded from all other phosphor areas by said opaque portions.
5. A storage light amplifier comprising an integral support plate formed of solid insulating material which includes an array of spaced transparent portions surrounded by opaque portions, electroluminescent phosphor areas adjacent to one side of said plate, and solid photoconductive plugs within said transparent portions supported by said

plate so that each photoconductive plug is optically coupled to a corresponding one of said phosphor areas through said transparent portions but is optically shielded from all other phosphor areas by said opaque portions, said optically coupled photoconductive plugs and phosphor areas being electrically connected together.

6. A storage light amplifier comprising a plate of solid insulating material which includes an array of apertured transparent portions each integrally surrounded by an opaque portion, electroluminescent phosphor areas adjacent to one side of said plate and exposed to the other side through said transparent portions, and solid photoconductive bodies supported in the apertures of said plate and each having surface portions which are exposed to a corresponding one of said phosphor areas but optically shielded from all other phosphor areas.

7. A storage light amplifier comprising a glass plate integrally formed with a network of opaque portions of the glass forming compartments with transparent portions of the glass therein, a solid photoconductive plug within each compartment extending from side to side of said plate and surrounded by one of said transparent portions, a mosaic of mutually insulated transparent conductive patches on one surface of said plate and registered with said compartments and connected respectively to said plugs, a layer of electroluminescent phosphor on said mosaic, conductive means on said phosphor layer, and conductive means on the other side of said glass plate, at least one of said last two conductive means being transparent to light.

8. A storage light amplifier as in claim 7, wherein the volume of transparent glass is substantially greater than the volume of opaque glass.

9. A storage light amplifier as in claim 7, wherein the volume of transparent glass is substantially greater than the volume of said photoconductive plugs.

References Cited in the file of this patent

UNITED STATES PATENTS

2,495,697	Chilowsky	Jan. 31, 1950
2,773,992	Ullery	Dec. 11, 1956
2,802,963	Sheldon	Aug. 13, 1957

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,975,291

March 14, 1961

Egon E. Loebner et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, line 2, and in the heading to the printed specification, line 4, name of the third inventor, for "Donald E. Darling", each occurrence, read -- Donald C. Darling --.

Signed and sealed this 17th day of October 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents

USCOMM-DC