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HIGH CAPACITY ELECTROLUMINESCENT LAYER

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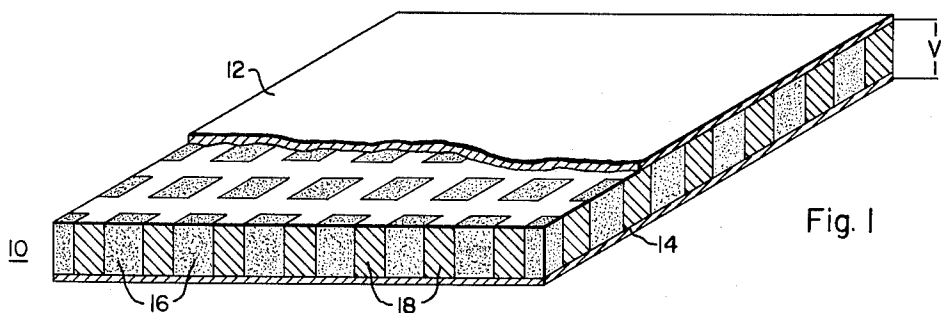


Fig. 1

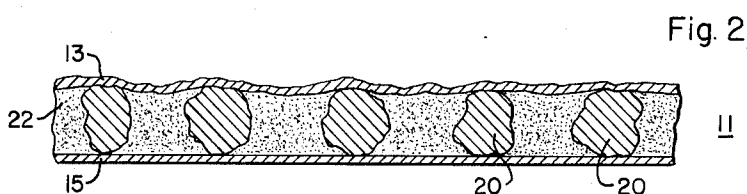


Fig. 2

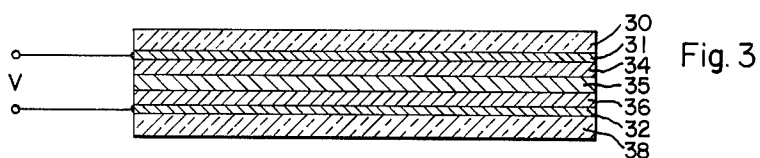


Fig. 3

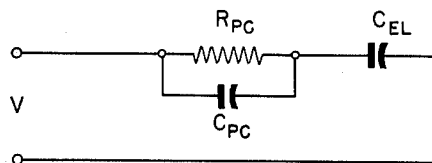


Fig. 4

WITNESSES

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HIGH CAPACITY ELECTROLUMINESCENT LAYER

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This invention relates to electroluminescent devices and, more particularly, to high capacitance electroluminescent layer devices such as find application in photoconductive-electroluminescent light amplifiers, display panels and switching devices.

By way of explanation, electroluminescence was first completely disclosed by G. Destriau in London, Edinburgh and Dublin Philosophical Magazine, series 7, volume 38, No. 285, pages 700-735 (October 1947), article titled "The New Phenomenon of Electroluminescence." In the phenomenon of electroluminescence, selected phosphor materials are placed within the influence of an electric field, such as by sandwiching the phosphor material between two spaced electrodes and applying an alternating potential between these electrodes. The resulting electric field which is created across the electrodes excites the phosphor materials to luminescence, and the phosphor materials which display this electroluminescence are thus termed "field responsive." Such phosphor materials are normally admixed with a dielectric material or a separate layer of dielectric material which is included between the electrodes in order to prevent any arcing thereacross which would short out the electroluminescent cell, but a separate dielectric is only desirable and not mandatory because the cells may be operated under some conditions without any dielectric where the applied electric field is as high as 100 kv. per centimeter. Normally, the spaced electrodes are parallel, but they need not be, as where graded field intensities are desired.

High capacitance electroluminescent layers are of great value in certain applications. For example, it is known that in display panels and switching devices embodying photoconductive and electroluminescent elements it is necessary that the capacitance of the electroluminescent element be high with respect to that of the photoconductive element. This type device commonly embodies, in a laminated cell construction, various lamina which for all practical purposes are arranged in the manner of an ordinary parallel-plate capacitor having dielectric materials interposed between the two plates. The plates are comprised of electrically conducting layers, such as tin oxide or gold, one of which is sufficiently thin to be transmissive of light radiation. The dielectric between the plates is comprised of two main parts. There is, a first layer of photoconductive material, such as cadmium sulfide which has a high dark electrical impedance and whose resistance decreases upon being irradiated by light radiation. A second layer, of electroluminescent material, which may be excited to luminescence by the application thereto of a variable electrical field is also provided. A typical suitable material for use as the electroluminescent layer is zinc sulfide and zinc selenide which have been activated by a halogen and copper or silver. If desired, an opaque insulating layer with low impedance may be provided between the photoconductive and electroluminescent layers. This opaque layer is provided if light feedback is not wanted or a pattern of an opaque layer may be applied if light feedback and separation of the photoconductive and electroluminescent layers is necessary. Instead of the insulating layer, a mosaic of opaque or transparent metal elements may also be used.

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Upon the application of an exciting alternating voltage between the two plates of the above device, the voltage is divided between the photoconductive and electroluminescent layers according to their impedances. The inclusion of an opaque layer does not appreciably influence this voltage division as its impedance is very small when compared with those of the photoconductive and electroluminescent layers and hence, for all practical purposes, may be neglected. Therefore, if the impedance ratio of the photoconductive layer of the electroluminescent layer is high, the applied voltage will be divided so that the photoconductive layer has as many times higher voltage than the electroluminescent layer as the value of this impedance ratio. Thus, the electroluminescent layer, in series with the photoconductive layer, has a low voltage and it will give very low or practically no light output. This is the desired condition for these solid state devices in the dark, i.e. when no light is falling on the photoconductor.

It is not, however, easy to fulfill this condition. In the above described "sandwich" or "layer on layer" construction of these photoconductive-electroluminescent devices the dark impedance of the photoconductive layer is defined practically by its capacitance. (The dark resistance is much higher than the parallel connected capacitive impedance.) Therefore, the impedance ratio is given by the capacitance ratio of the two layers according to the equation:

$$\frac{Z_{PC}}{Z_{EL}} = \frac{jwC_{EL}}{jwC_{PC}} = \frac{C_{EL}}{C_{PC}}$$

where Z is impedance, C is capacitance, w is the frequency multiplied by 2 π , $j = \sqrt{-1}$, PC refers to the photoconductive layer and EL to the electroluminescent layer. The above equation shows that a high impedance ratio of the photoconductive to the electroluminescent layer is equivalent to a high capacitance ratio of the electroluminescent to the photoconductive layer. As the dielectric constants of the photoconductive and electroluminescent layers are in the same order of magnitude, and the areas of the two layers are the same in the simple sandwich construction, for the necessary capacitance ratio of the two layers a thin electroluminescent layer and a thick photoconductive layer have to be used. Unfortunately, there are practical limits to the thickness of the electroluminescent layer and to the thickness of the photoconductive layer. The maximum brightness and the breakdown voltage are decreasing with decreasing thickness of the electroluminescent layer and the practical limit of the thickness for a plastic embedded electroluminescent layer is around 0.001 inch. Ceramic embedded electroluminescent layers are still thicker. As the photoconductive layer is increased in thickness, the conductivity (sensitivity) at a given illumination is decreased. This is due to the fact that the light is absorbed in the portion of the layer near the surface and the deeper lying portion remains in the dark and hence has a low conductivity (high resistance).

To overcome these difficulties, various constructions have been proposed, mostly utilizing the photoconductive material in a lateral cell structure whereby low capacitances are obtainable. These constructions are normally of a mosaic or lined (grooved) structure of elements which limit the resolution of the device and introduces complicated fabrication techniques.

It is, therefore, an object of this invention to provide an improved electroluminescent device.

A further object is to provide an electroluminescent layer with appropriate characteristics for the construction of a simple sandwich type display panel or switching device.

Another object is to provide an improved means for increasing the capacitance of an electroluminescent layer. Still another object is to provide an improved high capacitance electroluminescent device.

A still further object is to provide a radiation responsive device of the photoconductor-electroluminescent type in which the ratio of capacitance of the electroluminescent layer with respect to the photoconductive layer is high.

Briefly, the present invention provides that the capacitance of an electroluminescent layer may be substantially increased by providing, within the layer, substantially parallel paths, extending between opposing surfaces of said layer, of a first material capable of electroluminescence and a second material having a dielectric constant which is high with respect to the dielectric constant of the first material. Further, the invention provides a display device of the photoconductive-electroluminescent type utilizing the aforementioned high capacitance electroluminescent layer to provide that the ratio of capacitance of the electroluminescent layer with respect to the capacitance of the photoconductive layer is high, preferably five or greater.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawings, in which:

FIGURE 1 is a perspective view partially in section and partially broken away illustrating the invention in its preferred form;

FIG. 2 is a fragmentary sectional view of an electroluminescent layer showing a further embodiment of the invention of FIG. 1;

FIG. 3 is a diagrammatic view, in section, of a photoconductive-electroluminescent display panel embodying the present invention; and,

FIG. 4 is a schematic illustration of the equivalent circuit of the device of FIG. 3.

With reference now to FIG. 1, there is shown the invention in its preferred form. The device of FIG. 1 includes a layer indicated generally by 10, capable of electroluminescence, which is in the form of a slab or lamina. Disposed upon the two major surfaces of the layer 10 are two layers of electrodes 12 and 14 which are of electrically conductive material. At least one of the electrodes or layers 12 and 14 is transmissive of the light produced by the layer 10 and may be made of a very thin film such as tin oxide or gold. As illustrated in FIG. 1, the layer 10 is comprised of two regions 16 and 18 in the form of a regular pattern. The regions 16 are shown to be in the form of rectangular blocks which extend the full thickness of the layer 10 and are in contact with each of the two electrodes 12 and 14. Regions 16 are comprised of a suitable material capable of electroluminescence and may be any of the phosphors known in the art, for example zinc sulfide and zinc selenide which have been activated by a halogen and copper or silver. The regions 18 collectively form a mesh structure the thickness of which, like that of the regions 16, is substantially equal to the thickness of the layer 10 so that the surfaces of the regions 18 are also in contact with the two electrodes 12 and 14. The mesh or regions 18 are comprised of a material having a very high dielectric constant as compared to that of the material of regions 16. It has been found that ferroelectric materials, such as the titanates of barium, strontium, calcium, magnesium and lead as well as titanium dioxide, are suitable for this purpose. Preferably, the dielectric constant of the material of the regions 18 is at least 100.

It is thus seen that there is provided between the two electrodes 12 and 14 substantially parallel paths first of electroluminescent phosphor and second of the high dielectric constant material. Assuming now that the sur-

face areas of regions 16 and 18 are equal so that each provide 50% of the total surface of the layer 10 and assuming further that the dielectric constant of the material of the regions 18 is 100 while that of the material of the regions 16 is ten, it is apparent that the overall dielectric constant of the layer 10 is fifty-five. This represents an increase in the overall dielectric constant of the layer 10 of 5.5 times that of a layer comprised entirely of the electroluminescent material. It is, of course, evident that although as shown in FIG. 1 the pattern of regions 16 and 18 is a regular one, that an irregular pattern would serve as well.

One method by which the embodiment as shown in FIG. 1, or an irregular pattern, may be made is by spraying or otherwise depositing the mesh pattern 18 onto the electrode 14. This may be done by spraying or depositing through a mask the pattern of a powdered high dielectric material mixed with a binder onto the electrode 14. The dielectric powder may then be sintered, the binder baked out and the holes or interstices of the grid filled with the phosphor material of the regions 16. The mosaic form of FIG. 1 could also be made by flame spraying or screen masking or by the well known Kodak photo-resist method. If ceramic embedding is used for the phosphor, it could be deposited first. Principally, it is unimportant which material, that is either the electroluminescent material or the high dielectric constant material, is first placed down, the important feature being that substantially parallel paths are formed between the two opposing electrodes so as to increase by several hundred percent the total capacity of the layer.

It is not essential that a grid pattern be formed and the layer 10 may be made by depositing either a regular or irregular pattern of high dielectric constant material onto the substrate and filling up the empty areas with phosphor as in the previous method.

With reference now to FIG. 2, there is shown a modification of the device of FIG. 1. In this embodiment, a layer 11, similar to layer 10 of FIG. 1, is comprised of a plurality of either regularly or irregularly shaped balls or lumps 20 of high dielectric constant material. In the vacancies between the balls 20 the electroluminescent material 22, which may be any of those suitable for the embodiment of FIG. 1, is placed much in the manner as set forth above. This pattern may be either regular or irregular. Another method of forming the embodiment shown in FIG. 2 is by first depositing on a tin oxide (electrode 15) coated glass plate a continuous layer 22 of the electroluminescent material which is embedded in a plastic. The layer 11 is then heated and the balls 20, which are not smaller in diameter than the thickness of the electroluminescent layer, are forced into the softened phosphor-plastic layer. An upper electrode 13 is then disposed on the top of this combined layer 11.

With reference now to FIG. 3 there is shown a photoconductive-electroluminescent type image panel embodying the present invention. The device is shown as a laminated type structure having a first support member 30 which is of a suitable material transmissive to input radiation, for example glass. Disposed upon one surface of the support 30 is a radiation transmissive conducting film or electrode 31 which, as has been stated, may be tin oxide. Next in order is a layer 34 which is of photoconductive material, for example cadmium sulfide which is applied to the electrode 31. Disposed upon the free surface of the layer 34 is a layer 35 of opaque or transparent metal elements. An electroluminescent layer 36, any of the embodiments of the layers 10 and 11 discussed with respect to FIGS. 1 and 2, is positioned on the free surface of the layer 35. The size and distribution of the elements of the mosaic layer 35 is preferably chosen so that one element will cover a number of regions of high dielectric constant material and electroluminescent material of the layer 36. A second electrode 32 which may be vacuum deposited transparent gold or the same as electrode 31

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and a second support member 38 constitute the remaining portion of the laminated structure. A suitable potential V is connected to the two electrodes 31 and 32 to provide for a varying electric field across the layers 34 and 36.

It is, of course, obvious that in this instance where the electroluminescent layer of the present invention is utilized with a photoconductive layer, that the regions of high dielectric constant material and electroluminescent material do not extend between two electrodes. They do remain, however, substantially coextensive and extend between the electrode 32 and the layer 35 (or layer 34 were the choice not to include the layer 35).

In FIG. 4 there is shown the equivalent circuit of an element of the structure of FIG. 3. In FIG. 4, R_{PC} represents the resistance of the photoconductive layer 34 while C_{PC} represents the capacitance of that layer. These elements are shown to be in parallel. Connected in series with this parallel arrangement is a second capacitor C_{EL} which represents the capacitance of the electroluminescent layer 36. The ohmic component of the electroluminescent layer and the impedance of the opaque layer 35 are relatively unimportant and therefore they are not included in FIG. 4. As has been previously stated, the capacitance of the layer 36 should be at least five times greater than that of the capacitance of the layer 34 in order that the photoconductive-electroluminescent device should have the proper operating range and voltages. Thus C_{EL} divided by C_{PC} should be equal to 5 or more.

While there have been shown and described what are at present considered to be the preferred embodiments of the invention, modifications thereto will readily occur to those skilled in the art. It is not desired, therefore, that the invention be limited to the specific arrangements shown and described and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

I claim as my invention:

1. A high capacity electroluminescent device comprising first and second electrodes and a layer disposed between said electrodes, said layer comprising a material exhibiting the property of electroluminescence and having a first dielectric constant and a plurality of regions distributed throughout said layer having a higher dielectric constant than the dielectric constant of said electroluminescent material, each of said regions extending continuously between opposed surfaces of said layer so that the capacitance of said device is increased.

2. A high capacity electroluminescent device comprising first and second electrodes and a layer disposed between said electrodes, said layer comprising first and second regions, said first regions containing material capable of electroluminescence, the dielectric constant of said first regions being of a first value, and said second regions being of a second material, said second material having a dielectric constant higher than that of the material of said first regions, each of said first and second regions extending between opposed surfaces of said layer whereby said first and second regions provide substantially parallel paths between said surfaces so that the capacitance of said device is increased.

3. A high capacity electroluminescent device comprising first and second electrodes and a layer disposed between said electrodes, said layer comprising first and second regions, said first regions containing material capable of electroluminescence, the dielectric constant of said first region material being of a first value, said second regions being of a second material, said second material having a dielectric constant of at least 100, each of said first and second regions extending between opposed surfaces of said layer whereby said first and second regions provide substantially parallel paths between said surfaces so that the capacitance of said device is increased.

4. A high capacity electroluminescent device comprising first and second electrodes and a layer disposed between

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said electrodes, said layer comprising first and second regions, said first regions containing a material capable of electroluminescence and said second regions consisting of barium titanate, each of said first and second regions extending between opposed surfaces of said layer whereby said first and second regions provide substantially parallel paths between said surfaces so that the capacitance of said device is increased.

5. A high capacity electroluminescent device comprising first and second electrodes and a layer disposed between said electrodes, said layer comprising a mesh of a first material having a first dielectric constant, said mesh extending the distance across said layer between said electrodes and a second material capable of electroluminescence and having a dielectric constant less than that of said first material disposed within the interstices of said mesh whereby substantially parallel paths are formed between opposing surfaces of said layer so that the capacitance of said device is increased.

6. A high capacity electroluminescent device comprising first and second electrodes and a layer disposed between said electrodes, said layer comprising a mesh of material having a dielectric constant of at least 100 and extending across the distance across said layer between said electrodes and a second material capable of electroluminescence disposed within the interstices of said mesh whereby said mesh and said electroluminescent material form substantially parallel paths between opposing surfaces of said layer so that the capacitance of said device is increased.

7. A radiation responsive device comprising a laminated structure including in the order named, a radiation transmissive electrode, a radiation sensitive layer, a high capacitance electroluminescent layer, and a second electrode, said electroluminescent layer comprising first and second regions distributed throughout said layer, said first regions containing a material capable of electroluminescence and said second regions being of a material having a dielectric constant of at least 100, said second region forming a discrete path continuous between opposing surfaces of said electroluminescent layer so that the capacitance of said electroluminescent layer is increased.

8. A radiation responsive device comprising in the order named, a radiation transmissive electrode, a radiation sensitive layer, a high capacitance electroluminescent layer, and a second electrode, said electroluminescent layer comprising first and second regions, said first regions including a material capable of electroluminescence and said second regions consisting of barium titanate wherein said second region forms a discrete path continuous between opposing surfaces of said electroluminescent layer so that the capacitance of said electroluminescent layer is increased.

9. A radiation responsive device comprising a first electrode transmissive of input radiation, a first layer sensitive to said input radiation, a high capacitance second layer capable of electroluminescence, and a second electrode, said second layer comprising a mesh of material having a first dielectric constant, said mesh forming a discrete path across the thickness of said second layer, and a material capable of electroluminescence disposed within the interstices of said mesh, said latter material having a dielectric constant less than that of said mesh material.

10. A radiation responsive device comprising a first electrically conductive layer, a photoconductive element disposed in contact with said first conductive layer, a high capacitance electroluminescent element, and a second electrically conductive layer in contact with said electroluminescent element, said electroluminescent element comprising an electrical field responsive phosphor and a material of high dielectric, said phosphor and said material of high dielectric each forming discrete paths across said second layer in a parallel relationship to provide

that the capacitance of said electroluminescent element is at least five times the capacitance of said photoconductive element.

11. A radiation responsive device comprising a first electrically conductive layer transmissive of input radiation, a photoconductive layer disposed in contact with said first conductive layer, a high capacity electroluminescent layer, and a second electrically conductive layer in contact with said electroluminescent layer, said electroluminescent layer comprising first and second regions of, respectively, a first material capable of electroluminescence and barium titanate, said barium titanate and said first material each forming discrete paths in parallel relation between opposing surfaces of said electro-

luminescent layer so that the capacitance of said electroluminescent layer is increased.

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RALPH G. NILSON, *Primary Examiner.*