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DISTRIBUTED GAP ELECTROLUMINESCENT DEVICE

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Fig. 2.

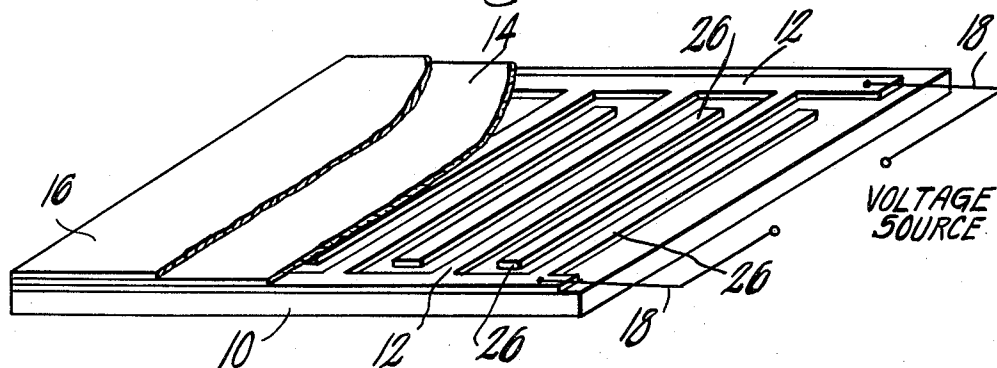
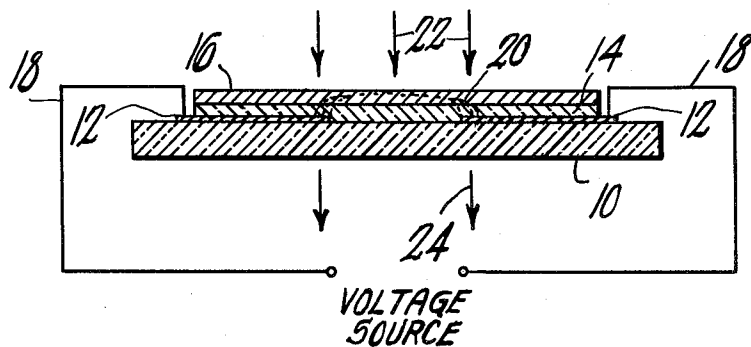


Fig. 1.



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DISTRIBUTED GAP ELECTROLUMINESCENT DEVICE

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8 Claims. (Cl. 250—211)

This invention relates to electroluminescent devices and particularly to electroluminescent devices adapted to reproduce incident radiation images.

It is known in the art that many phosphors may be caused to luminesce by subjecting them to electric fields. This phenomenon has been termed electroluminescence and may be effected by placing the phosphors between two electrodes adapted to have a potential difference applied therebetween.

Electroluminescence may be accomplished by suspending the phosphor in a transparent dielectric material prior to placing it between the electrodes. The application of a direct current voltage between the two electrodes will induce a burst of electroluminescence in the phosphor as an electric field builds up thereacross. The electroluminescence will cease when the full charge has been received and the electric field stabilized. The subsequent removal of the direct current voltage and discharge of the accumulated charge will produce a second burst of electroluminescence as the electric field collapses.

If an alternating current is applied between the two electrodes, bursts of electroluminescence will occur for each charge and discharge induced by such alternating current. For this reason, alternating current has been used in the past to produce seemingly constant electroluminescence, since if the frequency of the applied alternating current is high enough, the bursts of electroluminescence will occur at intervals shorter than the retentivity of the human eye, thus making the electroluminescence appear to be continuous.

However, electroluminescence may also be accomplished without suspending the phosphor in a dielectric material by providing the phosphor particles with suitable series resistance to prevent excess current flow through such particles. When a direct current voltage is applied of sufficient magnitude to cause a certain current flow, electroluminescence will occur. Such electroluminescence appears to be continuous and its intensity may be controlled by varying the current flow through the phosphor and series resistance.

There are several theories explaining the above described phenomena, none of which are entirely satisfactory, however, it seems to be agreed that the electroluminescence results from a redistribution of electrons in the crystal structure of the phosphors and the consequent emission of light from such material.

Electroluminescent devices have been constructed which are capable of producing or reproducing radiation images. Such devices usually comprise contiguous electroluminescent and photoconductive layers sandwiched between transparent electrodes. A difference of electrical potential, applied between the electrodes, is prevented from causing the electroluminescent layer to emit light by the high impedance of the photoconductive layer in the dark. However, if the photoconductive layer is illuminated its impedance will be reduced to a point at which electroluminescence may occur. Selective illumination of certain areas of the photoconductor will produce elec-

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troluminescence from selected areas of the electroluminescent layer thus making possible the production or reproduction of radiation images. However, it is difficult to provide a photoconductive layer of sufficient thickness to have the impedance necessary to control the electroluminescence layer and yet thin enough to be easily penetrated by incident radiation. Furthermore, the devices above described require electrodes on both sides of the layers which is not always desirable.

Therefore, it is an object of this invention to provide an electroluminescent device capable of producing electroluminescence in response to an incident radiation image in which the radiation responsive element may be thin enough to insure good penetration of such radiation.

It is a further object of this invention to provide an electroluminescent device capable of producing or reproducing radiation images and having electrodes on one side only.

It is yet another object of this invention to provide novel structures for electroluminescent devices.

Briefly, a device according to this invention may be constructed by placing a plurality of spaced electrodes on one surface of a layer or stratum of electroluminescent material and a variable impedance means (e. g. photoconductive material) in operative relation to the other surface of the electroluminescent layer or stratum.

In operation, a voltage is applied between the spaced conductors which is slightly less than that necessary to cause current flow sufficient to induce electroluminescence when the variable impedance means is at its maximum of impedance. When the impedance of the variable impedance means is reduced (as by the incidence of light on a photoconductive material) the decreased impedance of the variable impedance means will cause increased current flow between the conductors, and through the electroluminescent material which lies between the conductors and the variable impedance layer. The current flow will cause electroluminescence which will vary in intensity directly with such current flow.

The invention will be more completely understood when the following detailed description is read in conjunction with the appended single sheet of drawing in which:

Figure 1 is a cross-sectional view of an elemental embodiment of this invention; and

Figure 2 is a perspective view, partially broken away, of a device according to this invention.

Referring to Figure 1, and elemental embodiment incorporating the invention is shown, comprising an insulating transparent base plate 10, which may be glass, for example, and two spaced electrodes 12 having parallel adjacent edges and which may be applied to the glass by any convenient means. The electrodes 12 may be transparent electrodes, for example, which may be applied to glass by the deposition of the vapors of stannic acid, water and methanol thereon through a suitable mask. A layer 14 of electroluminescent material may be applied, by any convenient means, over the electrodes 12 and between the adjacent edges of such electrodes 12 onto the base plate 10. For example, the electroluminescent material may comprise a field responsive phosphor (e. g. zinc sulfide) suspended in or bound together by a plastic, and may be applied by a silk screening process. A layer 16 of a material which has a variable impedance characteristic in response to radiant energy excitation may be applied by any convenient means over the electroluminescent layer 14. The variable impedance material may comprise a photoconductive powder (e. g. copper activated cadmium sulfide powder) bounded together by plastic, for example, which may be applied by a silk screening process. Electrical connections 18 may be made to the electrodes 12 to enable the application of a voltage therebetween.

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In operation, a potential difference may be applied to the two electrodes 12 which is slightly less than that necessary to cause sufficient current flow to produce visible electroluminescence in the electroluminescent layer 14 when the variable impedance layer is at its maximum impedance. If the impedance of the variable impedance layer 16 is reduced, it will tend to facilitate current flow and will thus tend to induce electroluminescence in the portion of the electroluminescent layer 14 adjacent to the edges of the electrodes 12 and intervening between the electrodes 12 and the variable impedance layer. Dotted lines 20 represent generally the current flow lines which will occur as the impedance of the variable impedance layer 16 is reduced. It will be seen from such current flow lines 20 that the electroluminescence will occur at the edges of the electrodes 12 and will tend to extend across the electrodes 12 to the limits of the reduced impedance area of the variable impedance layer. Little or no electroluminescence will occur in the electroluminescent material intervening directly between the electrodes 12. Thus, it is desirable that the electrodes 12 be transparent to allow more efficient transmission of the electroluminescence produced. However, for some applications and in some structures, the electroluminescence occurring at the edges of opaque electrodes may be sufficient.

Since the electroluminescent material which lies in the spaces between the electrodes 12 does not produce electroluminescence at any time during operation, it may be replaced by a transparent insulating material (not shown). It is necessary only that the electrodes 12 be coated with the electroluminescent material. However, it is simple to apply a continuous coating of electroluminescent material and the insertion of the strips of insulating material would complicate the fabrication of the device to an extent that may nullify the advantages gained thereby for most applications of the device.

In the embodiment shown in Figure 1, the variable impedance layer 16 may comprise a layer of photoconductive material. Thus, the device will respond to incident radiations (indicated by arrows 22) to which the photoconductor is sensitive. The electroluminescence produced (indicated by arrows 24) will be dependent in intensity on the intensity of the incident radiations since the greater the reduction in the impedance of the photoconductive layer, the greater the current flow and thus, the greater the electroluminescence produced.

A particular advantage of devices constructed according to this invention is that the lateral impedance variation of the photoconductive layer provides the control of the device. Even a thin layer of photoconductive material will present considerable lateral impedance variations and will be capable of performing the control functions which would necessitate a comparatively thick photoconductive layer in prior art constructions. This enables the use of a photoconductive layer thin enough to be easily penetrated by even low intensity levels of incident radiations and thus the construction of a highly sensitive device.

The device, of which Figure 1 is a cross section, may be of any desired length depending on the application for which it is intended. If the entire length of the device is illuminated, electroluminescence will occur along its entire length. However, selected portions of the length of the device may be caused to electroluminesce by illuminating selected portions of the photoconductive layer 16. Thus, if a beam of light is allowed to fall on the photoconductive layer 16, electroluminescence will occur along the electrodes 12 in the area defined by the beam of light. In addition, if the entire device is illuminated, simultaneously, but to varying degrees of intensity at different portions thereof, such variation in intensity will be reproduced in the electroluminescence which occurs. If the photoconductive layer 16 is sensitive to the radiations emitted by the electroluminescent layer 14, feed

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back between the two layers may result. Such feed back may or may not be desirable depending upon the application for which the device is designed. If feed back is undesirable it may be avoided by interposing a thin opaque coating (not shown) between the two layers having the proper electrical characteristics. For example, where the electroluminescent layer comprises an electroluminescent phosphor suspended in plastic and alternating current is applied, the opaque coating may take the form of a non-conducting, blackened lacquer or paint.

It is apparent that a device constructed according to this invention is subject to many variations in structural parameters such as the spacing between electrodes, the width of electrodes, the thickness of the layers and the voltage applied. For example, if a higher operating voltage is desired, the spacing between the electrodes may be increased to provide the necessary increased impedance. An advantage accruing from such flexibility of structural design is that the device may be so designed that a comparatively thin photoconductive layer may be used, thus providing for the penetration of the radiation completely through such photoconductive layer 16 even at low intensities.

Referring to Figure 2, a device embodying this invention and adapted to reproduce radiation images is shown. An insulating transparent backing plate 10 may be provided with two electrodes 12. The electrodes 12 may have extending finger-like projections 26 which are interdigital and equally spaced from each other. Such electrodes may be formed by the deposition of the vapors of stannic acid, water and methanol onto a glass backing plate through a suitable mask, for example. Electroluminescent material, which may comprise a phosphor (e. g. zinc sulfide) suspended in a transparent insulating dielectric for example, may be applied over the interdigital portions of the electrodes 12 to form an electroluminescent layer 14. Photoconductive material (e. g. copper activated cadmium sulfide powder bound together by a plastic) may then be applied over the surface of the electroluminescent layer 14 to form the variable impedance layer 16. Both the electroluminescent material and the photoconductive material may be applied by any convenient means such as silk screening, for example. Electrical connections 18 may be made to the electrodes 12 to provide for the application of a potential difference thereto.

In operation, a voltage is applied between the electrodes 12 which is insufficient to cause enough current flow to produce visible electroluminescence so long as the photoconductive layer 16 is at its maximum value of impedance. The incidence of light on the variable impedance layer 16 will reduce the impedance thereof thus partially shunting a portion of the electroluminescent layer 14 between adjacent projections 26 of the electrodes 12 and facilitating current flow through the remaining electroluminescent material as described in connection with Figure 1. Such current flow will induce electroluminescence in the electroluminescent layer 16 as described.

Since the reduction of impedance of the photoconductive layer 16 is dependent on the intensity of the incident radiations, it is possible to produce electroluminescence at any portion of the surface of the device and of any desired intensity.

If an image is projected upon the device, a corresponding electroluminescent image will be produced since the varying light intensity of each elemental area of the projected image will be transformed by the device into varying electroluminescent intensity from each corresponding elemental area of the electroluminescent layer 16. The applied voltage may be either alternating or direct current as desired and depending on the construction of the device.

It is apparent that the resolution of an image produced by the device will be dependent upon the physical construction of the device itself. Thus, if the interdigital

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portions of the electrodes 12 are small enough and closely spaced enough so that the eye cannot resolve them when they are viewed from a certain distance, then the image produced thereby will exhibit good resolution at the same distance. Extremely small and closely spaced interdigital structures are readily obtainable by using silk screen masking techniques.

In a successfully tested device constructed by silk screen masking techniques, a sheet of glass 6 inches square was provided with two electrodes 12 having 100 interdigital projections 26. The projections 26 were 0.05 inch wide and were spaced from each other by 0.02 inch. An electroluminescent layer 0.001 inch thick and consisting of a zinc sulfide powder suspended in plastic was applied over the interdigital projections. A photoconductive layer 0.003 inch thick and consisting of a copper activated cadmium sulfide powder bonded together by plastic was applied over the electroluminescent layer. When an alternating current was applied to the device and an image allowed to impinge upon the photoconductive layer an electroluminescent image was produced which exhibited a resolution comparable to the width and spacing of the interdigital projections.

It will be apparent that the variable impedance layer may be responsive to any frequency of radiations depending on the material used. Thus, the device may be adapted to convert images of one frequency of radiations into images of another frequency. In addition, image or light amplification and image storage are possible in properly adapted embodiments of this invention. Thus, a new and useful device is herein provided which is readily adaptable to many systems, including television systems, and which will have many advantages over similar devices provided by the prior art.

What is claimed is:

1. An electroluminescent device comprising a plurality of spaced electrodes, electroluminescent material including portions overlying said electrodes, and variable impedance means including portions each overlying and electrically connecting the portions of said electroluminescent material which overlie adjacent ones of said plurality of electrodes for controlling current flow through said electroluminescent material.

2. An electroluminescent device as claimed in claim 1 wherein said variable impedance means comprises a material having a variable impedance characteristic in response to radiant energy excitation.

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3. An electroluminescent device comprising a plurality of spaced electrodes, electroluminescent material overlying said electrodes, and a layer of material having a variable impedance characteristic in response to radiant energy excitation adjacent said electroluminescent material.

4. An electroluminescent device as claimed in claim 3 wherein each of said plurality of spaced electrodes is provided with electrical connections whereby potential differences may be established between adjacent ones of said plurality of electrodes.

5. A light responsive device comprising a stratum of electroluminescent material, a stratum of photoconductive material on one surface of said stratum of electroluminescent material, and a plurality of spaced electrodes on the other surface of said stratum of electroluminescent material.

6. A light responsive device having a plurality of electrodes on only one side thereof comprising a layer of electroluminescent material, a layer of photoconductive material on one surface of said electroluminescent material, said plurality of electrodes being on the surface of said electroluminescent layer opposite said one surface.

7. An electroluminescent device comprising a layer of electroluminescent material, a layer of photoconductive material on one surface of said layer of electroluminescent material, and a plurality of spaced electrodes on the other surface of said electroluminescent material, said electrodes having projections extending along the surface of the electroluminescent layer and interdigital with each other.

8. A light responsive device comprising an insulating transparent base plate, a plurality of spaced transparent conductors on one surface of said base plate, said conductors having projections extending along the surface of said base plate and interdigital with each other, a layer of electroluminescent material on said conductors and said base plate, and a layer of photoconductive material on said electroluminescent layer.

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