

July 3, 1962

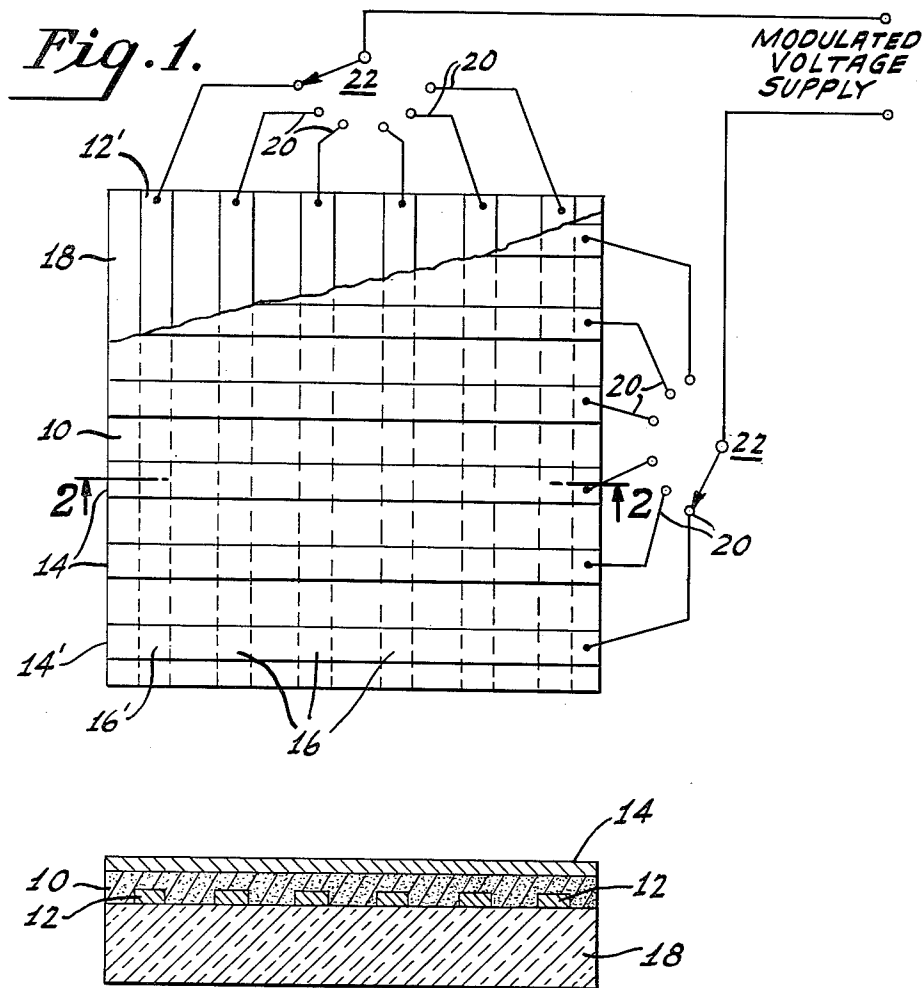
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3,042,834

ELECTROLUMINESCENT DEVICE

Filed Nov. 28, 1955

3 Sheets-Sheet 1



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Fig. 3.

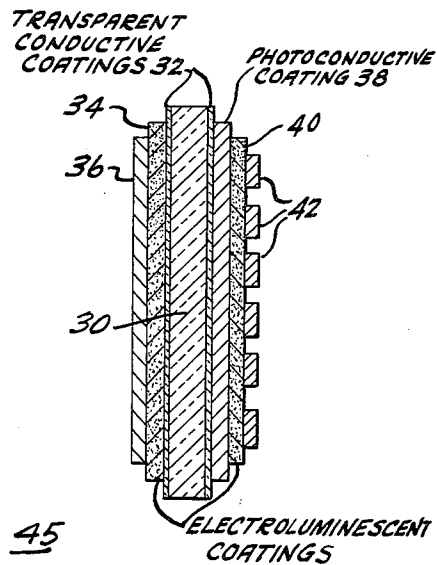
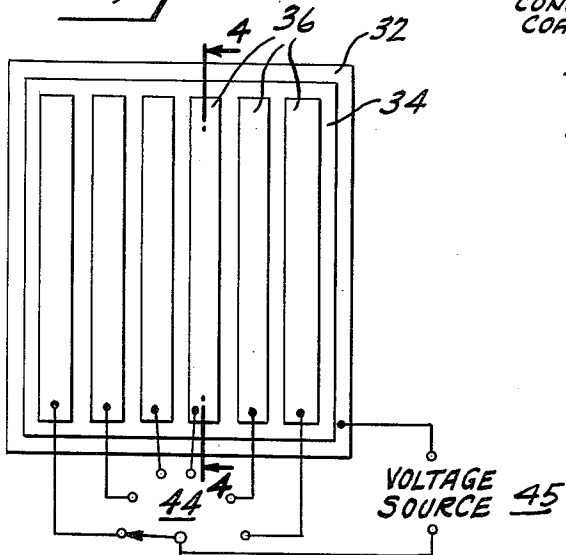


Fig. 4.

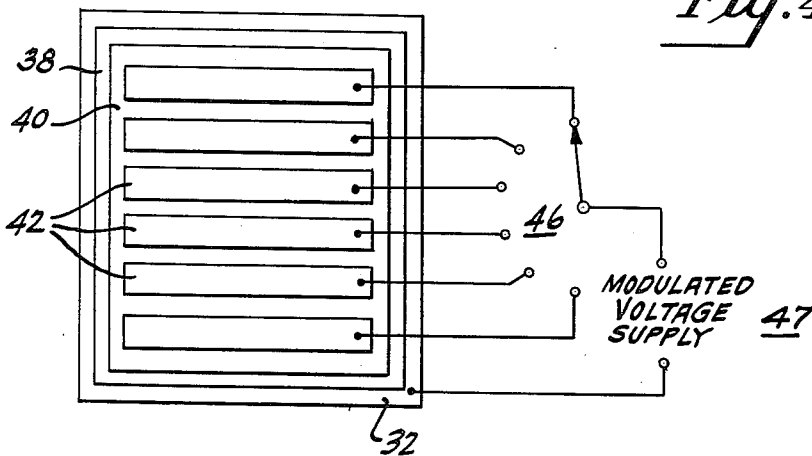


Fig. 5.

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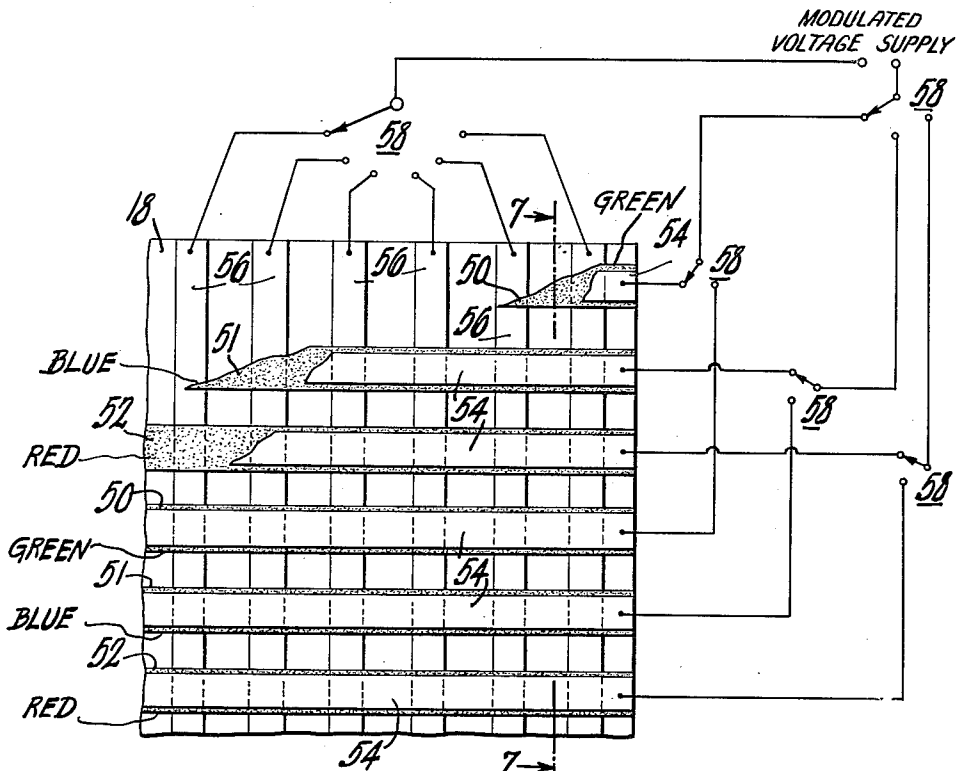


FIG. 6

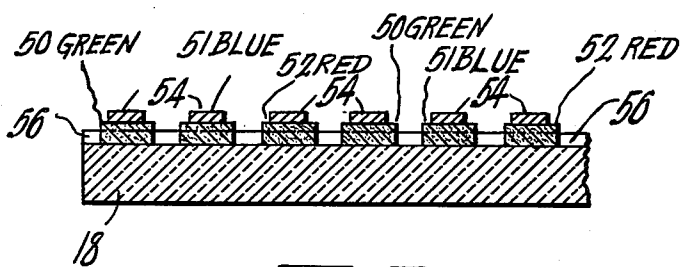


FIG. 7

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ELECTROLUMINESCENT DEVICE

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9 Claims. (Cl. 315-169)

This invention relates to electroluminescent devices, and particularly to electroluminescent devices adapted to produce or reproduce images by elemental scanning.

This application is a continuation-in-part of my prior copending application, Serial No. 476,267, filed December 20, 1954, and assigned to the same assignee, now abandoned.

It is known in the art that certain phosphors can be caused to luminesce by subjecting them to electric fields, different phosphors displaying different colors of luminescence. This phenomenon is called electroluminescence and may be effected by suspending the phosphor particles in a transparent dielectric material and placing the resulting electroluminescent phosphor material between electrodes. The application of direct current voltage to the electrodes will induce a burst of electroluminescence in the phosphor particles 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.

Similarly, if an alternating current voltage is applied to the electrodes, bursts of electroluminescence will occur for each charge and discharge induced by the alternating current voltage. For this reason, alternating current voltage has been used in the art to produce seemingly constant electroluminescence. That is, if the frequency of the applied alternating current voltage 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.

Several theories explaining the above described phenomena are currently in force, none of which are entirely satisfactory. However, it seems to be agreed that the electroluminescence above described results from a redistribution of electrons in the crystal structure of the electroluminescent phosphor and the consequent emission of light from such phosphor.

Electroluminescent devices of the prior art are customarily planar in form, comprising a sheet or layer of electroluminescent material sandwiched between flat conductors at least one of which is transparent or translucent. The principal object of such a device is to serve as an area source of light. It is not possible to produce or reproduce a variable intensity image with such a device by the application of voltages alone since the entire area thereof will luminesce uniformly.

Accordingly, it is an object of this invention to provide an improved electroluminescent device of which selected areas may be caused to luminesce individually.

It is a further object of this invention to provide an improved electroluminescent device which may be caused to produce a scanning or flying spot of luminescence.

It is another object of this invention to provide an improved electroluminescent device capable of producing light images or reproducing light images in response to electrical signals.

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

An electroluminescent display device comprises a first plurality of spaced conductors extending along a first surface and a second plurality of spaced conductors extending along a second surface parallel to such first surface and

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closely spaced therefrom. The conductors of the second plurality extend across the conductors of the first plurality of conductors such that if the pluralities extended along the same surface the conductors of one of the pluralities would intersect conductors of the other plurality. A layer of electroluminescent material intervenes between the two pluralities of conductors, at least in the regions where the conductors of the two pluralities cross over each other.

According to this invention a layer of photoconductive material and an auxiliary layer of electroluminescent material intervene between the pluralities of conductors to prevent spurious electroluminescence caused by capacitive coupling between the pluralities of conductors.

The invention will be more completely understood when the following detailed description is read in conjunction with the appended three sheets of drawing, wherein:

FIGURE 1 is a plan view of an electroluminescent display device;

FIGURE 2 is a sectional view taken along lines 2—2 of FIGURE 1;

FIGURE 3 is a plan view of one major surface of an electroluminescent display device embodying the invention;

FIGURE 4 is a sectional view taken along lines 4—4 of FIGURE 3; and

FIGURE 5 is a plan view of the other major surface of the device shown in FIGURE 3.

FIGURE 6 is a plan view of a device similar to that shown in FIGURE 1 and adapted to produce color images.

FIGURE 7 is a sectional view taken along lines 7—7 of FIGURE 6.

Referring to FIGURES 1 and 2, a device is shown which comprises a layer of electroluminescent phosphor material 10 applied over a first plurality of parallel conductor or conductive strips 12 and a second plurality of parallel conductive strips 14 applied to such layer of electroluminescent material 10, with the second plurality of parallel conductors or conductive strips 14 applied so that they extend across the first plurality of conductive strips 12. Each strip of the second plurality of conductive strips 14 crosses over every conductive strip 12 of the first plurality.

In operation, if a voltage is applied to a conductive strip of each plurality of conductive strips (conductive strips 12' and 14', for example), electroluminescence will be induced in the electroluminescent material 10 intervening between the strips 12' and 14' at the region 16' where the conductive strip 14' of the second plurality crosses over the conductive strip 12' of the first plurality. If a voltage is applied between strip 14' of the second plurality and successive strips 12 of the first plurality, a spot of electroluminescence will scan along such strip 14' moving from cross-over region 16 to cross-over region 16 as successive strips of the first plurality are energized. This operation may be repeated for each successive strip 14 of the second plurality to produce scanning of entire area of the device.

More specifically, the device may be constructed as described below. An insulating back plate 18 (glass, for example) may be given a transparent conductive coating (as by the deposition of the vapors of stannic acid, water, and methanol thereon). The transparent conductive coating may then be separated (by etching or cutting, for example) into parallel transparent conductive strips 12 which are electrically insulated from each other. A layer of electroluminescent material 10 may then be applied over the surface of the transparent conductive strips 12 and a second conductive coating applied to the electroluminescent material 10. The second conductive coating (e.g. aluminum applied by evaporation or silk screening) may also be separated into parallel insulated strips 14 as by etching or cutting. The electroluminescent material 10 may be electroluminescent phosphor particles

suspended in a suitable dielectric such as ethyl cellulose. The phosphor may be zinc sulfide with activator proportions of copper. For example, I have used zinc sulfide activated with approximately 0.08 percent copper.

Preferably, the strips 14 of the second conductive coating should be formed along lines transverse to the first strips 12, so that each of them will cross over all of the first strips 12. For example, the strips may cross at right angles as shown in FIGURE 1, in which it is apparent that the first strips 12 may be conveniently referred to as vertical strips and the second strips 14 may be referred to as horizontal strips for purposes of explanation. Means 20 for making electrical connections between any pair of vertical and horizontal strips (e.g. switches 22) may be provided. Thus, any cross-over region 16 in the device may be selected and caused to electroluminesce. If the horizontal strips 14 are energized successively from top to bottom and the vertical strips 12 are each energized once from left to right during the time that each horizontal strip 14 is energized, a spot of electroluminescence may be caused to scan the electroluminescent coating 10 in a manner similar to the scanning of an electron beam across the face of a kinescope. It will be understood that the cross-over region 16 may be made as small as desired by making the conductive strips 12 and 14 sufficiently narrow. By modulating the voltage which is applied to the device in synchronization with the scanning of the device, an electroluminescent image may be produced.

To accomplish the scanning above described, any one of a number of mechanical or electronic commutator systems may be used, for example multi-anode beam tubes with suitable circuits will produce a commutator system which would be useful in place of the switches 22 shown in FIGURE 1.

It will be seen that at least one of the pluralities of conductive strips 12 and 14 should be transparent. As stated above, the conductive strips 12 on the backing plate 18 where such backing plate is glass, may be conveniently transparent since a transparent conductive coating is easily applied to glass. However, if it is desired to use an opaque backing plate 18, the conductive strips 12 thereon may be metallic or any other convenient composition. The conductive strips 14 applied to the surface of the electroluminescent coating 10 must then be made transparent in order to allow the electroluminescence produced to be observed. Such transparent strips 14 may be conveniently provided in a number of different ways, for example, by applying a transparent conductive coating to a sheet of glass (not shown), separating such coating into strips and placing the strips in contact with the electroluminescent coating 10.

Although a layer 10 of electroluminescent material over the entire area of the backing plate 18 has been shown and described, it will be understood that it is only the electroluminescent material in the cross-over regions 16 that is essential to the operation of the device. Elemental areas of electroluminescent material at the cross-over regions 16 could be provided by silk screening through a suitable mask, for example. However, the layer construction shown and described is less complicated to fabricate and fully satisfactory where monochromatic images are desired.

While the device shown in FIGURE 1 is useful in many applications, it has the disadvantage that voltages applied across any pair of conductive strips 12' and 14' will be coupled to the rest of the conductive strips 12 and 14 in each plurality by capacitive coupling between the pluralities. It has been shown that the voltage appearing across each unselected cross-over region 16 in the device may be as much as $\frac{1}{2}$ of the voltage appearing across the selected cross-over region 16' due to such coupling. Thus, if the time for which each cross-over region 16 is selected is short, the contrast between the electroluminescence produced at the selected cross-over region 16' and the remaining cross-over regions 16 will be small since the

desired cross-over region 16' will luminesce for only a short period, whereas the remaining cross-over regions 16 will luminesce substantially all the time. Such lack of contrast will prevent the device from being useful for some applications.

The invention shown in FIGURES 3, 4, and 5 will eliminate the lack of contrast above described. Referring to FIGURE 4, a sheet of glass 30 may be given a transparent conductive coating 32 (as described above in connection with FIGURE 1) on both major surfaces thereof. An electroluminescent phosphor layer or coating 34, like the coating 10 of FIGURE 1, may be applied to one of the transparent conductive coatings 32 and conductive strips 36 may be applied to such electroluminescent coating 34 (as described above). A photoconductive coating or layer (e.g. copper activated cadmium sulfide powder in a suitable binder) 38 may be applied to the other transparent conductive coating 32, a second electroluminescent phosphor layer or coating 40 may be applied to such photoconductive coating 38 and conductive strips 42 may be applied to the second electroluminescent coating 40. The conductive strips 36 applied to the first electroluminescent coating 34 may extend in a vertical direction and the conductive strips 42 applied to the second electroluminescent coating 40 may extend in a horizontal direction, as shown in the drawing. Separate electrical connections 44 may be made to each of the conductive strips 36 on the first electroluminescent coating 34 such that a voltage may be connected between each of the strips 36 selectively and the conductive coating 32 on the corresponding surface of the sheet of glass 30. Similarly, separate electrical connections 46 may be made to each of the conductive strips 42 applied to the second electroluminescent coating 40 such that a voltage may be connected between each of such strips 42 selectively and the other conducting coating 32.

In operation, the energization of successive vertical strips 36 on the first electroluminescent coatings or layers 34 will produce successive vertical strips of electroluminescence or electroluminescent light. Such electroluminescence will be transmitted through the glass sheet 30, and the conductive coatings thereon 32, to the photoconductive layer 38. The incidence of the electroluminescence upon the photoconductive layer 38 will reduce the electrical impedance thereof in an area corresponding to the strip of electroluminescence. The application of a voltage between one of the horizontal strips 42 applied to the second layer 40 of electroluminescent material and the corresponding conductive coating 32 will tend to produce a horizontal strip of electroluminescence, but such electroluminescence will not occur so long as the impedance of the photoconductive layer 38 is unaffected. Thus, electroluminescence will occur along the strips 42 applied to the second electroluminescent coating 40, when energized, only at the area where a vertical electroluminescent strip induced in the first electroluminescent coating 34 crosses over such horizontal strips 42, reducing the impedance of the photoconductive layer 38 at that area.

As in FIG. 1, the conductive strips 42 on the output side of the device must be transparent to the light emitted by the electroluminescent layer 40.

By successively energizing the conductive strips 42 applied to the second electroluminescent layer 40, by means of a switch 46 and voltage source 47, and energizing the conductive strips 36 applied to the first electroluminescent layer 34, by means of a switch 44 and voltage source 45, once during the time that each conductive strip 42 on the second electroluminescent layer 40 is energized, a scanning spot of electroluminescence may be produced in a manner similar to that described with respect to FIGURE 1.

Coupling to unselected cross-over regions is prevented or diminished by the high impedance of the photoconductive layer in two ways. In the first instance, it will

not allow electroluminescence to occur in the second electroluminescent coating 40 unless its impedance is reduced by the incidence of radiation. Thus, electroluminescence is inhibited throughout the area of the device except at a strip coextensive with the strip of electroluminescence in the first electroluminescent coating. In the second instance, the photoconductive layer represents a high impedance between the conductive strips 42 on the second electroluminescent coating 40 and the second transparent conductive coating 32. This high impedance will reduce the capacitive coupling between the conductors 42 and the second transparent conductive coating 32 to a point below which it can cause any detrimental effect.

The voltage applied from source 47 to the conductive strips 42 on the second electroluminescent coating 40 may be modulated in synchronization with the scanning produced as described above in order to provide an electroluminescent image. Although the other voltage applied to the device from source 45 could be modulated to produce such image, it is more desirable to modulate the voltage applied to the conductive strips 42 on the second electroluminescent coating 40, since only a small area of electroluminescence is induced in the second electroluminescent coating 40 because of the action of the photoconductive layer 38. Thus, the signal loss in only one element is involved at any one time, whereas if the other voltage were modulated, signal losses along an entire line would be involved.

Although a sheet of glass 30 with transparent conductive coatings 32 on opposite surfaces thereof has been shown and described, a single transparent conductor could also be used. In operation, the transparent conductive coatings 32 shown may be electrically connected and grounded. Therefore, a single transparent conductor would be equally operative. Such a conductor could be provided by substituting a sufficiently thin metallic layer for the sheet of glass 30 and conductive coatings 32, for example.

In the invention shown in FIGS. 3-5, the electroluminescent coating or layer 40 is in contact with one plurality of conductive strips (42), like the electroluminescent layer 10 in FIG. 1. Instead of being also in contact with the other plurality of conductive strips (36), as in FIG. 1, the layer 40 is operatively associated with the strips 36 by means of the intervening coatings or layers 38, 32 and 34. Therefore, the limitation "operatively associated with" is intended to be generic to all of the embodiments of the invention disclosed.

Referring to FIGURE 6, a device is shown which is capable of producing or reproducing images in color. The device shown in FIGURE 6 is identical to that shown in FIGURE 1 with the exception that the electroluminescent material does not take the form of a layer but rather is divided into strips 50, 51 and 52 substantially co-extensive with each conductive strip 54 of one of the pluralities of conductive strips 54 and 56.

Phosphors which electroluminesce in the three primary colors of radiation may be used. In other words, one electroluminescent strip 50 will radiate light of the green frequency, the next adjacent electroluminescent strip 51 will radiate light of the blue frequency and the next adjacent electroluminescent strip 52 will radiate light of the red frequency and the cycle then repeated. Switching means 53 are provided whereby each electroluminescent strip 50, 51 and 52 of each color may be selected and voltage applied thereto. Thus, the device may be scanned in a manner similar to the scanning of the device shown in FIGURE 1, as described above, with the exception that different colors and different combinations of colors may be selected. It should be emphasized again that the electroluminescent phosphor need only intervene between the two pluralities of conductive strips 54 and 56 at regions where the conductive strips of each plurality

cross over each other. Thus, different color phosphors could be used at adjacent cross-over points rather than in adjacent electroluminescent strips 50, 51 and 52. Such construction would place additional demands upon the switching means 53 and upon the methods of fabricating the device.

It will be apparent to one skilled in the art that a new electroluminescent device is herein provided which is subject to many modifications for many purposes. It provides a new means of producing or reproducing images which is readily adaptable to most of the systems now in existence. Indeed, the device herein described may replace a cathode ray tube in most of its applications and with many new and unusual results.

What is claimed is:

1. An electroluminescent device comprising a transparent sheet at least the opposite surfaces of which are conductive, a first plurality of spaced elongated conductors extending along and spaced from one of said surfaces of said sheet, electroluminescent material intervening between said first plurality of conductors and said one surface of said sheet, a layer of photoconductive material on the other of said surfaces of said sheet, a second plurality of spaced elongated conductors extending along and spaced from the side of said layer of photoconductive material remote from said sheet, said second plurality of conductors extending transversely to said first plurality of conductors, and electroluminescent material intervening between said second plurality of conductors and said layer of photoconductive material at least in the regions of cross-over of said conductors of said first plurality and said second plurality, the conductors of at least said second plurality being transparent.

2. An electroluminescent device as in claim 1, wherein said transparent sheet comprises a sheet of glass having transparent conductive coatings on the opposite surfaces thereof.

3. An electroluminescent device comprising a transparent sheet at least the major surfaces of which are conductive, a first electroluminescent layer on one major surface of said sheet, a first plurality of spaced parallel elongated conductors on said electroluminescent layer, a photoconductive layer on the other major surface of said conducting sheet, a second electroluminescent layer on said photoconductive layer, and a second plurality of spaced parallel elongated conductors on said second electroluminescent layer and extending transverse to said first plurality of conductors.

4. An electroluminescent device comprising a transparent sheet at least the major surfaces of which are conductive, a first layer of electroluminescent material on one major surface of said sheet, a first plurality of spaced elongated conductors on said first layer of electroluminescent material, a photoconductive layer on the other major surface of said sheet, a second layer of electroluminescent material on said photoconductive layer, a second plurality of spaced elongated conductors on said second layer of electroluminescent material, said second plurality of spaced elongated conductors extending transverse to said first plurality of spaced elongated conductors, means including electrical connections and a switching device for applying electrical potential differences between each of said first plurality of spaced elongated conductors independently and said sheet, and means including electrical connections and a switching device for applying electric potential differences between each of said second plurality of spaced elongated conductors and said sheet.

5. An electroluminescent device including: a first unit comprising a first layer of electroluminescent material, a first array of spaced parallel elongated conductors on one side of said first layer, and a first conductive layer on the other side of said first electroluminescent layer; a second unit comprising a layer of photoconductive material, a second layer of electroluminescent material in contact with said photoconductive layer, a transparent

second conductive layer on one side of said second unit, and a second array of spaced parallel elongated conductors on the other side of said second unit; and means mounting said units in adjacent parallel relation with said photoconductive layer exposed to light emitted by said first electroluminescent layer, and with the conductors of said second array extending transverse to the conductors of said first array.

6. An electroluminescent device as in claim 5, further including means for applying electric potential differences between said first conductive layer and each conductor of said first array, and means for applying electric potential differences between said second conductive layer and each conductor of said second array.

7. An electroluminescent device as in claim 5, wherein said mounting means comprises a sheet of glass interposed between and joined to said units.

8. An electroluminescent device including: a first unit comprising a first layer of electroluminescent material, a first plurality of spaced parallel elongated conductors on one side of said first layer, and a first conductive layer on the other side of said first electroluminescent layer; a second unit comprising a layer of photoconductive material, a transparent second conductive layer on one side of said photoconductive layer, a second layer of electroluminescent material on the other side of said photoconductive layer, and a second plurality of spaced parallel elongated conductors on the side of said electroluminescent layer opposite said photoconductive layer; and means mounting said units in adjacent parallel relation with said photoconductive layer exposed to light emitted by said first electroluminescent layer, and with said second plurality

of conductors extending transverse to said first plurality of conductors.

9. An electroluminescent device including: a first unit comprising a first planar array of spaced parallel elongated conductors and a first conductive layer in spaced parallel relation to said first array; a second unit comprising a second planar array of spaced parallel elongated conductors and a transparent second conductive layer in spaced parallel relation to said second array; and means mounting said units in adjacent parallel relation with the conductors of said second array extending transverse to the conductors of said first array to form a multiplicity of cross-over regions therebetween at the intersections thereof; said first unit further comprising electroluminescent material between said first array and said first conductive layer at least in said cross-over regions; said second unit further comprising photoconductive material and electroluminescent material in series between said second array and said second conductive layer at least in said cross-over regions; said photoconductive material being exposed to light emitted by the electroluminescent material in said first unit.

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