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ELECTROLUMINESCENT DEVICE

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This invention relates to electroluminescent devices.

It is known in the art that may phosphors may be caused to emit radiations by subjecting them to electric fields. This phenomenon has been termed electroluminescence and may be effected by placing the phosphor between two electrodes adapted to have a potential applied thereacross. If the phosphor is suspended in a transparent dielectric material prior to placing it between the electrodes, the application of a direct current voltage across 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.

Obviously, if an alternating current voltage is applied across the two 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 since, 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.

Electroluminescence may also be produced by providing each particle of the electroluminescent phosphor with a suitable series resistance to prevent excess current flow through any of such particles. When a direct current voltage of sufficient magnitude is applied to the phosphor particles and series resistances, a certain current will flow and electroluminescence will be induced in the phosphor. Such electroluminescence appears to be continuous and its intensity may be controlled by varying the amount of current flow through the phosphor particles.

Several theories explaining the above described phenomenon have been advanced, 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 electroluminescent material and the consequent emission of radiations from such material.

An electroluminescent device capable of producing or reproducing images may consist of a stratum of electroluminescent material having a plurality of spaced conductors on each surface thereof. The conductors on one surface of such stratum extend transversely to the conductors on the other surface of the stratum such that each conductor on one surface of the stratum will cross over every conductor on the other surface. Thus, by applying a voltage between a conductor on each surface of the stratum of electroluminescent material, a spot of electroluminescence may be induced in the electroluminescent layer corresponding to the cross-over point or region of such conductors. By selective energization of

the conductors on each side of the electroluminescent stratum, a spot of electroluminescence may be caused to scan over the electroluminescent stratum. Further, if the voltage applied to such conductors is modulated and synchronized with the selection of the conductors, an image may be produced.

However, it is found that capacitive coupling will occur between the various conductors on each side of the electroluminescent stratum. Such capacitive coupling reduces the contrast obtainable from the device since it has been shown that the voltage appearing across each of the unselected cross-over points may be as high as ½ of the voltage appearing across the selected cross-over point. Such lack of contrast obtainable from the device makes it inefficient for many applications.

It is an object of this invention to provide an electroluminescent device capable of responding to the coincidence of at least two separate light signals.

It is another object of this invention to provide an electroluminescent device of which selected areas may be caused to luminesce independently of other areas of the device.

It is a further object of this invention to provide an electroluminescent device capable of producing light images or of reproducing light images in response to an electrical signal with a high degree of contrast.

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

Briefly, this invention provides an electroluminescent element and a pair of photoconductive elements connected in series, and an electric field applied thereacross. With no light incident upon the photoconductive elements, the electroluminescent element will not be induced to luminesce due to the high impedance of such photoconductive elements. Similarly, if light is incident upon only one photoconductive element, the electroluminescent element will not be induced to luminesce due to the high impedance of the remaining photoconductive element. However, if both photoconductive elements of the pair are illuminated, their impedance will be reduced to a point low enough to allow the electroluminescent element to be induced to luminesce. The use of a pair of photoconductive elements makes possible the control of the electroluminescent element in response to the coincidence of two separate energizing signals.

According to an embodiment of this invention, a plurality of electroluminescent elements and associated pairs of photoconductive elements are arranged in approximately the same plane. Each photoconductive element of each pair of photoconductive elements is offset from the other such that one of each pair lies along a row in one direction and the other of each pair lies along a row in a transverse direction. Thus, one photoconductive element of each pair in a row extending in one direction may be illuminated by an elongated light source such as an electroluminescent strip extending in that direction, and the other photoconductive element of each pair in a row extending in a transverse direction may be illuminated by another elongated light source extending in the transverse direction. Thus, both photoconductive elements of only one pair will be illuminated by the elongated light sources. In order to produce an image either the voltage applied across the electroluminescent elements or the light produced by the elongated light sources may be modulated in synchronization with a scanning of the electroluminescent elements.

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

Figure 1 is a schematic representation of a single electroluminescent element and the pair of photoconductive

cells connected in series therewith, according to this invention.

Figure 2 is a perspective view of a device constructed according to this invention.

Figure 3 is a perspective view, partially broken away, of a portion of a device according to this invention.

Referring to Figure 1, an elementary unit 10 according to this invention is shown schematically. A voltage source is connected across an electroluminescent element 12 and two photoconductive elements 14 in series. When no light is incident upon the photoconductive elements 14, they will exhibit a very high impedance (e.g. practically an open circuit) and substantially all of the voltage drop in the circuit will appear across them. If one of the photoconductive elements 14 is illustrated, the photoconductive element 14 remaining unilluminated will continue to act substantially as an open circuit. Therefore, it is necessary that both photoconductive elements 14 be illuminated in order for any effective amount of the applied voltage to appear across the electroluminescent element 12. Thus, the electroluminescent element 12 will be induced to emit light only when both photoconductive elements 14 are illuminated.

According to one embodiment of this invention, the photoconductive elements 14 are physically located, with respect to each other so that one may be illuminated independently of the other. Thus, it is possible to control the light emitted by the electroluminescent element 12 in accordance with two separate sources of radiation, one for each of the photoconductive elements 14.

Referring to Figures 2 and 3, a device is shown which incorporates a plurality of the above described elemental units 10 and which may be utilized to produce an electroluminescent image. The plurality of units 10 are arranged so as to form a plurality of rows extending in at least two directions across the surface of a backing plate 16, which may be glass for example. That is, the plurality of units 10 may be arranged so as to form, for example, a plurality of horizontally aligned rows and a plurality of vertically aligned rows across the surface of the backing plate 16. One of the photoconductive elements 14 of each unit is located with respect to the unit 10 such that it will be aligned with the corresponding photoconductive elements 14 of all the units 10 of a row extending in one direction. The other photoconductive element 14 of each unit 10 is likewise aligned with the corresponding photoconductive elements 14 of all the units 10 of a row extending in another direction. However, the photoconductive elements 14 of each unit 10 are so arranged with respect to each other that they are not both aligned with a row extending in the same direction.

A plurality of elongated light sources 18 and 19 (such as radiation emitting strips) may be juxtaposed adjacent to the plurality of units 10 arranged as described above. Part 18 of the plurality of radiation emitting strips may be aligned with rows of photoconductive elements 14 extending in one direction and the remaining 19 radiation emitting strips may be aligned with rows of photoconductive elements 14 extending in the other direction. The radiation emitting strips 18 and 19 should, of course, emit radiations to which the photoconductive elements 14 are sensitive. Thus, by energizing a radiation emitting strip 18 extending in one direction and another radiation emitting strip 19 extending in a transverse direction, one and only one of the units 10 may be rendered capable of producing electroluminescence since only one unit 10 will have both of its photoconductive elements 14 illuminated. Part of the remaining units 10 will have only one of their photoconductive elements 14 illuminated and the rest of the units 10 will have neither of their photoconductive elements 14 illuminated.

The device will be more completely understood by referring to the partially broken away perspective view of a portion thereof, shown in Figure 3. According to the embodiment shown in Figure 3, the device may consist of a backing plate 16 and two scanning plates 30 and 32 all of which may be glass sheets, for example. A plurality of parallel, spaced, transparent conducting strips 22 are deposited on one surface of the backing plate 16. Such strips 22 are readily produced on glass by the deposition of the vapors of stannic acid, water and methanol thereon through a suitable mask. An opaque insulating coating 34 may then be applied over the remaining surface of the backing plate 16. The opaque coating 14 may consist of any one of a number of blackened laquers, varnishes or paints which may be sprayed or painted onto the backing plate 16 through a suitable mask adapted to protect the conducting strips 22. Electroluminescent material may then be applied to the transparent conducting strips 22 by any convenient means, such as silk screening, so that strips 24 of electroluminescent material substantially co-extensive with the transparent conducting strips 22 are produced. Conductive material to form the electrodes 26 of the electroluminescent elements 12 and the electrodes of the photoconductive elements 14 may be applied by printed circuit techniques or by silk screening. The conductive material may be a metallic paste such as aluminum or silver paste for example. The electrodes 26 for the electroluminescent elements 12 are distributed on and along each of strips 24 of electroluminescent material at regularly spaced intervals. The electrodes 26 may be generally rectangular in shape and coextensive with an area of the electroluminescent strip 24 which is elemental in size with relation to the size of the image to be produced. Each electrode 26 may be aligned with corresponding electrodes 26 on adjacent electroluminescent strips 24. Each electrode may have a projection 28 extending beyond the electroluminescent strip onto the opaque insulating coating 34 to serve as one electrode of the first photoconductive element 14 of each unit 10. A conductive member 25 spaced from each of such projections 28 on the opaque insulating coating 34 may serve as the other electrode of the first photoconductive element 14 and as one of the electrodes of the second photoconductive element 14. The conductive member 25 may be of generally L shape to provide an offset between the two photoconductive elements 14, the ends of the conductive member serving as the electrodes of the photoconductive elements 14. A conducting strip 27 may be interposed between adjacent electroluminescent strips 24 on the opaque insulating coating 34 and spaced from the above described projection 28 and conducting member 25. The conductive strips 27 may be provided with projections 29 extending therefrom into close proximity to one end of the L shaped conducting member 25. Photoconductive material applied between the ends of the L-shaped conductive member 25 and the projections 28, 29 from the electrodes 26 and the conducting strips 27 complete the construction of the photoconductive elements 14. The photoconductive material may consist of a photoconductive powder (e.g. cadmium sulfide) and may be bonded together by plastic and applied by any convenient means.

The scanning plates 30 and 32 (e.g. sheets of glass) may have a transparent conducting coating 36 applied over one entire surface thereof as by the deposition of the vapors of stannic acid, water and methanol thereon. Spaced, parallel strips 38 of electroluminescent material may be applied to the transparent conductive coating 36 and conductive strips 40 may be applied to the electroluminescent strips 38 so as to be co-extensive therewith. The conductive strips 40 may be made of metallic paste, for example. The electroluminescent strips 38 and the conductive strips 40 may be applied by any convenient means such as silk screening through a suitable mask. The plates 16, 30, 32 may then be placed together such that the unprocessed surface of the first scanning plate 30 is in contact with the processed surface of the back-

ing plate 16 and the unprocessed surface of the second scanning plate 32 is in contact with the processed surface of the first scanning plate 30. The electroluminescent strips 19 on the first scanning plate 30 are aligned with rows of photoconductive elements 14 of the various units 10 extending in one direction and the electroluminescent strips 18 on the second scanning plate 32 are aligned with rows of photoconductive elements 14 of the various units 10 extending in a transverse direction. According to the embodiment shown in Figure 3, the electroluminescent strips 19 on the first scanning plate 30, when properly aligned, extend in a horizontal direction, whereas the electroluminescent strips 18 on the second scanning plate 32 extend in a vertical direction. For clarity of explanation, the electroluminescent strips 19 on the first scanning plate 30 will hereafter be referred to as the "horizontal strips" and the electroluminescent strips 18 on the second scanning plate 32 will be referred to as the "vertical strips," although it is obvious from the description heretofore given that the strips could extend at a number of different angles to each other and to the horizontal and still accomplish the objects of this invention.

In operation, and referring to Figures 2 and 3, a voltage source is connected between the transparent conducting strips 22 and the strips 27 of conductive material on the backing plate 16. Thus, a voltage is applied across each of the plurality of units 10 on plate 16, but no electroluminescence will result since the voltage will be dropped across the high impedance of the photoconductive elements 14 in their unilluminated state. Electrical connections are made to each of the electroluminescent strips 18 and 19 on the two scanning plates 30 and 32 such that a voltage may be applied to each of the strips 18 and 19 independently of all the others. This may be accomplished by switching arrangements 42 as shown in Figure 2. The switches 42 may be mechanical, or electronic in operation depending on the application for which the device is to be adapted. Thus, if a horizontal electroluminescent strip 19 and a vertical electroluminescent strip 18 are energized, they will each illuminate a series of photoconductive elements 14. However, only one unit 10, located approximately at the point where the two strips 18 and 19 cross over each other, will be rendered capable of electroluminescence by having both of its photoconductive elements 14 illuminated.

By energizing one horizontal electroluminescent strip 19 and then each vertical strip 18 in sequence, each unit 10 along the horizontal strip 19 may be caused to electroluminesce in sequence. Similarly, by energizing each horizontal strip 19 in sequence and each vertical strip 18 in sequence once during the time that each horizontal strip 19 is energized, the various units 10 on the surface of the backing plate 16 may be scanned in a manner similar to the scanning of an electron beam across the face of a cathode ray tube.

In order to produce an image, any one of the voltage sources may be modulated in synchronization with the above described scanning of the device, each unit 10 of the device forming one element of the image produced. In some instances and for some purposes, it may be desirable to modulate two or more of the voltage sources in order to produce a desired image.

It is apparent that the device, above described, is capable of reproducing images in response to electrical signals. Further, it is apparent that each unit of the device is adapted to be energized independently of the others, thus providing for proper contrast in the image produced.

In Figures 2 and 3, the thickness of the various coatings and elements has been exaggerated for the purpose of illustration. Actually, such coatings and elements are usually very thin in relation to the thickness of a sheet of glass and thus do not lend themselves to ease of explanation.

The embodiment of this invention shown in Figures 2 and 3 is subject to many structural variations without departing from the teaching of this invention. For example, the opaque insulating coating 34 may take the form of an opaque insulating mask interposed between the first scanning plate 30 and the elements 14, 20, 22, 24, 25, 26 and 27, and having apertures therethrough in registry with the photoconductive elements 14. If such an opaque insulating mask is used, then a single scanning plate 30 having electroluminescent strips 36 on both surfaces thereof extending transversely to each other may be used in place of the two scanning plates 30 and 32 each having one set of electroluminescent strips.

The device disclosed is readily adaptable to existing television systems, both color and monochromatic. A significant advantage of this device is that it may take the form of a thin flat screen where a desired image may be produced without the need for projection systems, large kinescopes, or any other space consuming apparatus.

What is claimed is:

1. A radiation emitting device comprising an electroluminescent element and two spaced photoconductive elements, said three elements being electrically connected in series with each other, and means including a plurality of light sources for independently illuminating said photoconductive elements.

2. A radiation emitting device comprising a plurality of electroluminescent element and two spaced photoconductive elements, said three elements being electrically connected in series with each other, and means including electroluminescent cells each adjacent to a different one of said photoconductive elements for independently illuminating said photoconductive elements.

3. A scanning electroluminescent device comprising a plurality of electroluminescent cells, a plurality of photoconductive cells, pairs of said plurality of photoconductive cells being electrically connected, each of said electroluminescent elements being electrically connected in series with a different one of said pairs of said photoconductive cells and means for selectively illuminating both photoconductive cells of any one of said pairs of photoconductive cells.

4. The scanning electroluminescent device of claim 3 in which said means for illuminating said photoconductive cells comprises a plurality of strips of electroluminescent material each of which may be selectively induced to luminesce.

5. The scanning electroluminescent device of claim 3 in which said means for illuminating said photoconductive cells comprises a first plurality of strips of electroluminescent material extending in one direction and a second plurality of strips of electroluminescent material extending transversely to said one direction, and means for selectively inducing luminescence from one strip of each of said pluralities.

6. An electroluminescent picture reproducing device comprising a first transparent insulating plate, spaced parallel transparent conductive strips extending across one major surface of said first plate, a plurality of elemental areas of electroluminescent material distributed along alternate ones of said conductive strips, an electrode on each of said elemental areas of electroluminescent material, a plurality of pairs of spaced photoconductive cells on said plate along one side of said alternate strips, each of said plurality of pairs being electrically connected in series between one of said electrodes on said elemental areas of electroluminescent material and one of the other conductive strips, a second transparent insulating plate having one major surface adjacent said electrodes on said elemental areas and said photoconductive cells, a plurality of electroluminescent strips on the other major surface of said second plate and aligned with one photoconductive cell of said plurality of pairs of photoconductive cells, a third transparent insulating plate having one major surface adjacent said electroluminescent strips on

said second plate and electroluminescent strips extending across the other major surface of said third plate transversely of said first electroluminescent strips and aligned with the other photoconductive cells of said plurality of pairs of photoconductive cells.

7. The electroluminescent picture reproducing device of claim 6 in which said elemental areas of electroluminescent material are distributed along said conducting strips to form pluralities of rows extending in at least two transverse directions, one of said photoconductive cells of each of said plurality of pairs of photoconductive cells being aligned with one of said pluralities of rows extending in one direction and the other of said photoconductive cells of each of said plurality of pairs of photoconductive cells being aligned with one of said pluralities of rows extending in a transverse direction.

8. A display device comprising a plurality of elemental electroluminescent cells arranged in rows and columns; and means, including at least one photoconductive element operatively associated with each row and column and means for independently illuminating said photoconductive elements, for selectively connecting each electroluminescent cell to a voltage source.

9. A display device comprising a plurality of units arranged in rows and columns, each unit comprising a pair of terminals and an electroluminescent cell and a photoconductive element in series across said terminals, means for selectively illuminating each column of photoconductive elements to render all of the units in said column conductive, and means for selectively connecting all of the terminals of each row of units to a voltage source, whereby light will be emitted only from the electroluminescent cell of that unit located at the intersection of the particular column and row that are selected.

10. A display device as in claim 9, wherein the last mentioned means includes an additional photoconductive element operatively arranged in each unit to electrically energize the same upon illumination of said additional element.

11. A display device as in claim 9, wherein said last mentioned means includes an additional photoconductive element in series electrically with each unit, and means for selectively illuminating each row of said additional elements.

12. A display device as in claim 11, wherein the means for selectively illuminating the columns and rows of photoconductive elements includes a plurality of vertically arranged electroluminescent strips aligned with said columns of photoconductive elements and a plurality of horizontally arranged electroluminescent strips aligned with said rows of additional elements.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,914,678 November 24, 1959

Benjamin Kazan

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

Column 1, line 16, for "may" read -- many --; column 3, line 15, for "illustrated" read -- illuminated --; column 6, lines 27 and 28, for "a plurality of" read -- an --; line 31, before "electroluminescent" insert -- a plurality of --.

Signed and sealed this 12th day of July 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents