An electroluminescent display panel includes a first plurality of addressing conductors, a second plurality of addressing conductors forming a plurality of intersection regions with the first plurality of addressing conductors, each intersection region having associated with it an electrical series combination of an electroluminescent element of phosphor material of the d.c. kind as hereinafter defined electrically connected to the member of the first plurality of addressing conductors forming the intersection region and a photosensitive latch electrically connected to the member of the second plurality of addressing conductors forming the intersection region, the combination being arranged so that when light is emitted from the electroluminescent element it is incident on the latch, and each intersection region having associated with it a by-pass channel incorporating an electrical isolating element connected commonly to the electroluminescent element, and the latch associated with that intersection region, whereby a voltage may be applied across the electroluminescent element belonging to that intersection region without being applied across the associated latch. The isolating elements may be capacitors, non-linear diodes or semiconductor glass (amorphous) threshold switches. The latches may be photoconductors or photocapacitors.

10 Claims, 2 Drawing Figures
FIG. 1.

FIG. 2.
ELECTROLUMINESCENT DISPLAY PANEL WITH SWITCHING VOLTAGE PULSE MEANS INCLUDING PHOTOSENSITIVE LATCHES

BACKGROUND TO THE INVENTION

The present invention relates to electroluminescent display panels.

In designing electroluminescent display panels of the kind in which a plurality of regions, i.e. elements, of electroluminescent phosphor material can be contemporaneously excited by the direct application of an electric field across each of them, one of the major problems encountered is concerned with addressing the elements, i.e. selectively applying the electric fields. If a panel has a small number of elements it is possible for this purpose to connect either a pair of addressing conductors to each individual element or one addressing conductor to each individual element and the other to all of the elements. However, when the number of elements is large these arrangements become complex, because the number of addressing conductors required is also large. These arrangements may be avoided by using a known X/Y matrix addressing arrangement. The elements are arranged in rows and columns; a separate conductor is electrically connected to all of the elements in each given row and a separate conductor is connected to all of the elements in each given column. In this way a panel having n^2 elements requires only 2n addressing conductors instead of n^2 or 2n^2 as in the arrangements mentioned above.

However, if the matrix addressing arrangement is used it is difficult to energise the elements selected to be lit to give a particular display without partially energising those not so selected, because the addressing conductors are common to all of the elements in a given row or column. One known way in which this problem can be solved is to connect a separate latch, i.e. an electrically operated switch, in series with each element. When a latch is in a conducting state its impedance is much lower than that of its associated element; however, when the latch is in a non-conducting state its impedance is much higher than that of its associated element.

Therefore, if an operating voltage is applied across all of the elements only those elements whose associated latches are in a conducting state are energised.

U.S. Pat. No. 3,753,231 describes a matrix addressed panel whose electroluminescent phosphor material is of a kind responsive to unidirectional operating voltages and which incorporates semi-conductor glass (amorphous) memory switches as latches.

OBJECT OF THE INVENTION

It has been found that the latches used in the panel described in U.S. Pat. No. 3,753,231 may be difficult to deposit in large numbers having uniform properties. Therefore it is an object of the present invention to provide in an electroluminescent display panel of the kind having phosphor material responsive to unidirectional operating voltages, i.e. phosphor material of the d.c. kind as described hereinafter, latches of an alternative form.

SUMMARY OF THE INVENTION

According to the present invention an electroluminescent display panel includes a first plurality of addressing conductors, a second plurality of addressing conductors forming a plurality of intersection regions with the first plurality of addressing conductors, each intersection region having associated with it an electrical series combination of an electroluminescent element of phosphor material of the d.c. kind as hereinafter defined electrically connected to the member of the first plurality of addressing conductors forming the intersection region and a photosensitive latch electrically connected to the member of the second plurality of addressing conductors forming the intersection region, the combination being arranged so that when light is emitted from the electroluminescent element it is incident on the latch, and each intersection region having associated with it a by-pass channel incorporating an electrical isolating element connected commonly to the electroluminescent element and the latch associated with that intersection region, whereby a voltage may be applied across the electroluminescent element belonging to that intersection region without being applied across the associated latch.

Each of the by-pass channels may be connected in parallel with its associated latch to the member of the second plurality of addressing conductors to which its associated latch is connected. Alternatively, each of the by-pass channels may be connected to a member of a third plurality of addressing conductors.

The isolating elements can for instance be capacitors, diodes such as Schottky barriers, or non-linear impedances such as amorphous threshold switches.

The photosensitive latches can for instance be photoconductors or photocapacitors.

The panel is preferably formed as a matrix construction in which the electroluminescent elements and their associated latches are in rows and columns with the members of the first plurality of addressing conductors running along the rows and with the members of the second plurality of addressing conductors running along the columns. If the third plurality of conductors is included in the panel its members are preferably arranged also to run along the columns.

The panel may be formed on one surface of an optically transparent substrate such as glass, with the latches deposited in recesses having opaque walls in the surface of the substrate.

The panel is preferably operated by applying across selected electroluminescent elements and their associated isolating elements at least one switching voltage pulse capable of producing sufficient light emission from those selected electroluminescent elements to switch their photosensitive latches into a conductive state and by applying at a time when those latches are in the conductive state an operating voltage across all of the said series combinations causing light to be emitted from the selected electroluminescent elements. The isolating elements are necessary to isolate the electroluminescent elements from one another when the switching voltage pulse(s) is (are) being applied across the selected electroluminescent elements.

Embodiments of the present invention will now be described with reference to the drawings filed with the Provisional Specification, in which

FIG. 1 is a circuit diagram of the circuit arrangement of an electroluminescent display panel embodying the present invention.
FIG. 2 is a cross-sectional diagram illustrating the construction of part of the panel whose circuit arrangement is illustrated in FIG. 1.

DESCRIPTION OF THE Preferred EMBODIMENTS

The circuit shown in FIG. 1 has a simple $2 \times 2$ element matrix for illustration purposes. However, a matrix of a much larger number of elements can be produced in an identical form if required. The circuit includes two rows addressing conductors $X_1$ and $X_2$ and four column addressing conductors $Y_1$, $Y_2$, $Y_3$, and $Y_4$. A separate intersection region is formed between the conductors $X_1$, $Y_1$ and $Z_1$, between the conductors $X_2$, $Y_2$, and $Z_2$, and between the conductors $X_2$, $Y_3$, and $Z_2$. The intersection region between the conductors $X_1$, $Y_1$ and $Z_1$ consists of an electroluminescent element EL1 of the kind (described below) fabricated for unidirectional voltage operation electrically connected to the conductor $X_1$ and an isolating capacitor $C_1$ connected electrically to the conductor $Z_1$ and to the element EL1; and a photoconductive latch PC1 (shown as a light-operated switch) electrically connected to the conductor $Y_1$ and to the midpoint between the capacitor $C_1$ and the element EL1, which midpoint is denoted in FIG. 1 by the reference symbol $S_1$. Likewise, the other three intersections consist of electroluminescent elements EL2, EL3, and EL4 identical with the element EL1 respectively connected to the conductors $X_2$ and $Y_2$; capacitors $C_2$, $C_3$ and $C_4$ respectively connected to the conductors $Z_2$, $Z_1$, and $Z_3$ and to the elements EL2, EL3, and EL4; and photoconductive latches PC2, PC3, and PC4 respectively connected to the conductors $Y_2$, $Y_1$, and $Y_2$ and to the electrical mid-points between the capacitor $C_2$ and the element EL2, between the capacitor $C_3$ and the element EL3, and between the capacitors $C_4$ and the element EL4, which mid-points are denoted in FIG. 1 by the respective reference symbols $S_2$, $S_3$, and $S_4$.

The elements EL1, EL2, EL3, and EL4 are arranged so that when operated they can illuminate respectively the latches PC1, PC2, PC3, and PC4.

One method of operation of the device described with reference to FIG. 1 is as follows. Suppose that it is desired to operate the intersection region containing the element EL1, the capacitor $C_1$, and the latch PC1. A short switching voltage pulse (or a series of short switching voltage pulses) is applied between the conductor $X_1$ and the conductor $Y_1$. The pulse has (or the pulses have) a magnitude and duration capable of producing sufficient light output from the element EL1 in series with the capacitor $C_1$ to cause the latch PC1, on which light emitted by the element EL1 is incident, to be converted from a resistive state into a conductive state. A unidirectional operating voltage is applied between the conductor $X_1$ and the conductor $Y_1$ from the start of the switching voltage pulse or pulses. This voltage has a magnitude suitable for producing sufficient light output from the element EL1 in series with the latch PC1 to keep the latch PC1 in its conductive state, but has a magnitude typically less than that of the switching voltage pulse or pulses. The feature of using a voltage magnitude which is higher when the voltage is in pulsed form than when it is in essentially continuous form is discussed in copending United Kingdom Patent Application No. 54,853/72. When the latch PC1 is in the conductive state the operating voltage appears essentially completely across the element EL1. This allows emission from the element EL1 to be maintained and allows the latch PC1 to be maintained in the conductive state.

The other selected intersections are operated in a similar way.

The operating voltage may be applied for as long as light emission is required from the element EL1. This period is chosen with regard to the operating life characteristics of the element EL1. When it is desired to terminate the period of light emission from the element EL1 it is necessary to reduce significantly the voltage appearing across the element EL1. This can be done by altering the potential of the conductor $X_1$, the conductor $Y_1$ or the conductor $Z_1$ in such a way that the voltage across the element EL1 is reduced by the required amount. When the voltage appearing across the element EL1 is reduced, the level of the light emitted from the element EL1 decays and the latch PC1 relaxes back into the resistive state.

The means by which the operating voltages are applied and by which the intersections are selected and the switching pulse(s) are gated to them, i.e. by which the intersections are addressed, are well known in the art. They are described for example in copending U.K. Patent Application No. 54,853/72 (U.S. Ser. No. 362,705).

The channels between the elements EL1 (EL1 etc) and the Z conductors in which the capacitors C (C1 etc) are incorporated are necessary as by-passes to the latches PC (PC1 etc). If the switching voltage were applied directly across each appropriate combination of a latch PC and an element EL the major proportion of that voltage would appear across the latch PC and would not energise the element EL sufficiently to illuminate and hence switch the latch.

The capacitors C1, C2, C3, and C4 are used in the bypass channels to allow each intersection region to be independently latched. If they were not included there would be a short circuit via the conductor $Z_1$ between the point $S_1$ and the point $S_3$ and a short circuit via the conductor $Z_2$ between the point $S_2$ and the point $S_4$. This would cause light emission from the elements EL1 and EL3 together and from the elements EL2 and EL4 together.

The capacitance of each of the capacitors C is chosen to be comparable to or greater than that of each of the elements EL to allow the elements EL to be addressed with a short switching voltage pulse.

Each switching voltage pulse lasts typically for about 2 microseconds and has a magnitude of about 100 volts for a typical electroluminescent element formed at 60 volts (as discussed below). In the case of the intersection region containing the element EL1 the pulse is preferably applied by applying a negative electrical potential pulse of between about 50 volts to the conductor $X_1$ and contemporaneously applying a complementary positive electrical potential pulse of between about 50 volts to the conductor $Z_1$. The pulse is applied to other intersections in a similar way.

The electroluminescent phosphor material of the elements EL and the photoconductive material of the latches, are chosen so that the latches will be switched into their conductive state by the light emitted following the application of a 100 volt pulse lasting 2 μs but not by the light emitted following the application of a 50 volt pulse lasting 2 μs. This is not difficult in princi-
ple since for a typical electroluminescent phosphor material formed at 60 volts (as discussed below) the light emission for a 100 volt 2 μs pulse is typically 200 foot-lamberts whereas that for 50 volt 2 μs pulse is typically only 0.5 foot-lamberts. The operating voltage has a magnitude of about 60 volts for a typical electroluminescent element. This may be applied in the case of the intersection region containing the element EL1 by maintaining the conductor Y1 at a positive potential between about 40 and 60 volts and by maintaining the conductor X1 at a complementary negative potential between 20 and 0 volts. The operating voltage may if required be in the form of a train of unidirectional voltage pulses having a magnitude less than that of the switching voltage pulse, i.e. a magnitude of about 60 volts.

The latches PC require a period of up to about 1 or 2 milliseconds after light of the appropriate level has been incident on them before they reach the conductive state on conversion from the resistive state. They require a period of typically 5 milliseconds after the light level has significantly decayed before they are converted back into their original resistive state. Therefore, in order to terminate light emission from the element EL1 (for instance) it is necessary to reduce significantly the voltage across that element for a period of about 10 milliseconds. One way of achieving this is to apply a 10 millisecond positive electrical potential pulse typically of 25 volts to the conductor X1 and a 10 millisecond negative electrical potential pulse typically of 25 volts contemporaneously to either the conductor Y2 or the conductor Z2. The positive pulse reduces the voltage across the element EL1 causing the level of light emitted from the element to drop sufficiently to allow the latch PC1 to relax back into its resistive state. The negative pulse cancels the effect of the positive pulse on the electroluminescent elements whose light emission is not required to be terminated.

Further contemporaneous pulses may be applied to the conductors addressing other intersection regions in order that any changes in the voltages applied across those other intersections caused by terminating light emission from the element EL1 are compensated for. In another embodiment of the invention each of the isolating capacitors C can be replaced by an isolating diode such as a Schottky barrier diode, or by an element having a non-linear electrical impedance such as an amorphous threshold switch, such as a switch made from the material having the composition: 48 percent Te, 30 percent As, 12 percent Si and 10 percent Ge. The diodes or the elements having a non-linear impedance would have the same isolation function as the capacitors C.

In the case of the embodiment in which amorphous threshold switches are incorporated the switching voltage pulse or pulses would be such as to produce sufficient power in each threshold switch to cause that switch to be converted from its resistive state into its conductive state. The switch relaxes to its resistive state after the switching voltage pulse or pulses finish, owing to the absence of a holding current.

In another embodiment of the invention each of the photoconductive latches PC can be replaced by a separate photocapacitor latch whose capacitance can be varied between a relatively high value and a relatively low value according to the level of light incident on it. Such a device would be operated in the same way as that described with reference to FIG. 1, except that the operating voltages in this case would have to be in the form of a series of unidirectional pulses.

In another embodiment of the invention, the conductor Y1 and the conductor Z1 may be combined and the conductor Y2 and the conductor Z2 may be combined, so that the photosensitive latch and the isolating element of each intersection region are connected in electrical parallel, but this arrangement may be used only when the isolating elements are capacitors.

Suppose that this arrangement is used and also that the element EL1 and EL2 are already operating but that the elements EL3 and EL4 are not.

The element EL3 may be addressed with a switching pulse without affecting the element EL4 because the steady positive operating potential (i.e. about 60 volts) on the conductor Y2 does not combine with the switching voltage pulse (i.e. about 50 volts) applied to the conductor X2. The reason for this is that the steady operating potential is held off from the element EL4 by the capacitor C4 and the latch PC4 (which is in a resistive state). The capacitors C will only respond to short pulses. Also, the switching pulse (about 50 volts) applied to the conductor X1 which adds to the steady operating potential on that conductor does not seriously affect the operation of element EL1 since the switching voltage pulse is applied only for about 2 μs. The element EL1 merely emits more brightly for about 2 μs.

United Kingdom Patent Specification No. 1,300,548 describes a method of manufacturing an electroluminescent phosphor material suitable for use with the application of unidirectional electric fields, e.g. suitable for use in connection with the present invention. Basically, the method is as follows. An admixture is formed of particles of a compound or compounds of an element of Group Ib with an element of Group VIIb (such as zinc sulphide) and an activator such as manganese. The particles of the admixture are then coated with an electrically conducting element of Group Ib (such as copper). The coated particles are embedded in a translucent binding matrix (such as polymethylmethacrylate) to form a piece (normally a layer) of phosphor material. An electrode is attached to one part of the piece and another part of the piece. A unidirectional voltage is applied between the electrodes. This produces an electrical current in the piece of phosphor material. This current produces a localised region of high electrical resistivity within the piece of a phosphor material near the positive electrode.

Alternatively, material suitable for the application of unidirectional electric fields may be provided by the deposition on a suitable substrate such as glass (or glass bearing previously deposited conductive layers) of a thin film of phosphor material by evaporation. A localised region of high electrical resistivity is then formed in the film in a manner similar to that described above.

In any method of producing a piece of phosphor material suitable for use with the application of unidirectional electric fields (including the methods described above), one of the most essential steps is that of producing the localised region of high electrical resistivity. It is from this region that light emission occurs during operation of a device made from the piece of material. The step of producing the region is known as "forming". Forming may be carried out by the application of a steady voltage (typically, although not essentially, 25
volts) between the electrodes for a short period (typically, although not essentially, 2 or 3 minutes) until the piece of phosphor material is capable of weakly emitting light (at a level of about 5-10 foot-lamberts), followed by the application of a steadily increasing voltage between the electrodes at an approximately constant power (typically, although not essentially, 2 watts per sq cm) through the piece of phosphor material over a longer period (typically, although not essentially an hour) until a maximum voltage is reached. This type of forming is known as d.c. forming at approximately constant power.

The voltage magnitudes of 100 volts and 60 volts mentioned above in connection with the device described reference to FIG. 1 and are both appropriate for elements of electroluminescent phosphor material formed using a forming voltage of about 60 volts (a typical forming voltage).

Electroluminescent phosphor material which contains electrically conducting material added to it, whereby it may be electrically formed to produce a localised region of high resistivity, will be referred to herein as phosphor of the d.c. kind.

FIG. 2 is a cross-sectional diagram of part of an electroluminescent display panel embodying the invention. The panel is an integrated constructional form of the circuit described with reference to FIG. 1; the part illustrated is the integrated constructional form of the intersection region in FIG. 1 between the conductors X1, Y1 and Z1 and containing the element EL1, the capacitor C1 and the latch PC1. A transparent glass substrate 1 has on one surface a laterally running recess 3 produced by etching or some other suitable technique. The surface of the transparent glass inside the recess 3 has a region 5 of opaque glass. A strip 7 of conducting material, such as aluminium, is deposited in the recess 3 and extends along the entire length of the recess 3. A layer 9 of photoconductive material, such as cadmium sulphide, is deposited over a localised part of the layer 7. A strip 11 of transparent conducting material running parallel to the strip 7 is deposited on the substrate 1 adjacent to the recess 3, but electrically insulated from the strip 7 and layer 9. A layer 13 of dielectric material, such as silicon dioxide, is deposited over a metalized part of the strip 11 and adjacent to the layer 9. A layer 15 of transparent conducting material is deposited over the layer 13 and extends to cover the layer 9. A layer 17 of electroluminescent phosphor material produced in the manner described above is deposited over the layer 15. A strip 19 of conducting material running in a direction perpendicular to that of the strips 7 and 11 is deposited over the layer 17.

The strips 7, 11 and 19 are represented in FIG. 1 by the conductors Y1, Z1 and X1 respectively. The layer 9 is represented in FIG. 1 by the latch PC1. The layer 13 is represented in FIG. 1 by the capacitor C1. The layer 15 is represented in FIG. 1 by the point S1. The layer 17 is represented in FIG. 1 by the element EL1.

The recess 3 and the region 5 are provided to prevent light other than from the layer 17 from reaching the layer 9.

The complete panel will contain a matrix of structures each identical with that described with reference to FIG. 1 and formed on the surface of the substrate 1. The strip 19 will be common to a row of the structures and the strips 7 and 11 will be common to a column of the structures. Further similar strips will be common to the other row(s) and column(s). Normally, all of the structures will be fabricated contemporaneously using conventional deposition steps.

In operation, light from the layer 17 is transmitted through the glass substrate 1 and is observed to be emitted from the surface of the glass substrate 1 opposite to that having the recess 3. It is convenient for operation of an electroluminescent element in an integrated structure to arrange that the high resistivity region of the element is adjacent to the transparent conductor through which the emitted light is to be transmitted. Therefore the layer 17 is preferably electrically formed in such a way that its high resistivity region is adjacent to the strip 11. The layers in the other structures are electrically formed in a similar way.

The thicknesses of the layers 9 and 13 will depend on the electrical properties required of them. The optimum thickness can be found by either experimentation or theory. However the layer 13 has a thickness typically less than 1 μm, and the layer 9 has a thickness typically about 10 μm.

We claim:

1. An electroluminescent display panel including a first plurality of addressing conductors, a second plurality of addressing conductors forming a plurality of intersection regions with the first plurality of addressing conductors, each intersection region having associated with it a first electrical series combination of an electroluminescent element of phosphor material of the d.c. kind electrically connected to the member of the first plurality of addressing conductors forming the intersection region and a photosensitive latch electrically connected to the member of the second plurality of addressing conductors forming the intersection region, the first combination being arranged so that when light is emitted from the electroluminescent element it is incident on the latch, and each intersection region having associated with it a by-pass channel incorporating an electrical isolating capacitor connected to commonly to the electroluminescent element and the latch associated with that intersection to form a second series combination from said electroluminescent element and said capacitor, whereby a voltage pulse may be applied across the electroluminescent element without being applied across the latch, means for applying a switching voltage pulse across selected ones of said second series combinations in selected intersection regions to cause light emission from the electroluminescent elements thereof sufficient to cause the impedance of the latches in the first series combinations of said selected intersection regions to be reduced and means for applying across said first series combinations of said selected intersection regions of unidirectional energizing voltage capable of sustaining light emission of the electroluminescent elements in said selected intersection regions whilst said latches have a reduced impedance.

2. A panel as claimed in claim 1 and wherein each of the electrical isolating elements is electrically connected to the same member of the second plurality of addressing conductors as its corresponding latch.

3. A panel as claimed in claim 1 and wherein the panel includes a third plurality of addressing conductors, each of the electrical isolating elements being electrically connected to a member of the third plurality of addressing conductors.
4. A panel as claimed in claim 2 and wherein the said series combinations are arranged in a matrix formation, with each of the members of the first plurality of addressing conductors electrically connected to all of the elements of electroluminescent phosphor material in a corresponding row of the matrix and with each of the members of the second plurality of addressing conductors electrically connected to all of the latches in a corresponding column of the matrix.

5. A panel as claimed in claim 3 and wherein the said intersection regions are arranged in a rectangular row and column matrix formation, with each of the members of the first plurality of addressing conductors electrically connected to all of the elements of electroluminescent phosphor material in a corresponding row of the matrix, with each of the members of the second plurality of addressing conductors electrically connected to all of the latches in a corresponding column and with each of the members of the third plurality of addressing conductors electrically connected to all of the isolating elements in a corresponding column.

6. A panel as claimed in claim 1 and wherein the latches are photoconductors.

7. A panel as claimed in claim 1 and wherein the latches are photocapacitors.

8. A panel as claimed in claim 1 and wherein the addressing conductors, the said electrical series combinations and the electrical isolating elements are all formed in an integrated structure on one surface of an optically transparent substrate.

9. A panel as claimed in claim 8 and wherein the said surface contains opaque-walled recesses and the said latches are deposited in said opaque-walled recesses.

10. A panel as claimed in claim 1 and wherein the means for applying the switching voltage pulse provides a pulse having a duration of a few microseconds and a magnitude greater than the forming voltage of the panel and wherein the means for applying the energization voltage produces a voltage approximately equal to the forming voltage of the panel.