PATENT SPECIFICATION

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(54) ELECTROLUMINESCENT DISPLAY PANELS

(71) We, WESTINGHOUSE ELECTRIC CORPORATION of Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania, United States of America, a company organised and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electroluminescent display panels. In such panels, an X-Y array of display elements or cells, are provided upon an insulated substrate, and are interconnected together to produce a large area flat panel display which is substitutable for a cathode ray tube. Each of the display elements of the array comprises integral thin film transistor switching and control circuit elements, which are used to selectively address specific areas of the planar electroluminescent phosphor layer which is excited to produce light output in a display pattern.

Such an electroluminescent display panel is described in copending application No. 46911/76, Serial No. 1563243. As described in the copending application, the electroluminescent display panel is fabricated by vacuum depositing sequential layers of selected materials to form the X-Y array of display elements on an insulative substrate. Each display element covers an equal area of the panel, and a substantial portion of the area of the display element is occupied by the individual thin film circuit elements and particularly by the requisite spacing between such elements to prevent unwanted electrical interaction between the elements. For high resolution applications the physical size and area of this display element must be reduced, and this further increases the percent area of each display element taken up by the thin film circuit elements as opposed to the electrode. This electrode is the only portion of the display element which actually excites the electroluminescent phosphor which is disposed uniformly over the panel. The actual size of the thin film cirfcuit elements cannot readily be reduced because of the need to maintain desired electrical characteristics. This is particularly true with respect to the storage capacitive element which is required in one embodiment of the addressing circuit utilized for such an electroluminescent display panel. In order to achieve a large enough capacitive value for this storage capacitor, its effective area is relatively large.

In the above described copending application, a technique for effectively isolating the electroluminescent phosphor layer from the thin film circuit elements and the drive signal buses is set forth. A laminated photo-polymerizable layer is provided over such thin film circuit elements and the signal buses to thus effectively isolate the electroluminescent phosphor from these electrical components. This laminated photo-polymerizable layer is applied in a relatively thick layer with the photo-polymerizable insulative layer being selectively removed from the areas over the electrode to permit contact of such electrode with the phosphor layer which is then deposited over such electrodes and over the insulative polymerized portions which cover the thin film circuitry and signal bus elements.

The brightness and resolution of such electroluminescent display panels has been limited by the effective area of the electroluminescent phosphor layer which is in contact with and excited by individual electrodes. Till now this lit area has been about fifteen percent of the panel area. It is, therefore, highly desirable that the electrodes be extended to cover a greater area of the total panel area.

According to the present invention an electroluminescent display panel comprises an X-Y array of display elements each of which comprises integral thin film transistor switching and control circuit elements disposed on an insulative panel substrate and interconnected by drive signal buses, and each display element including an individual electrode disposed on the substrate, with an electrically insulative polymerized layer over the thin film elements and the signal buses, with an electroluminescent phosphor disposed over the entire panel area in contact with the individual electrodes and over the insulative polymerized layer, the individual electrodes extending from the insulative substrate and covering a substantial portion of the insulative polymerized layer.

The inventon also includes a method of fabricating an electroluminescent display panel comprising a thin planar insulating substrate having an X-Y array of display elements thereon each of which display elements includes integral thin film transistor switching and control circuit elements disposed on the insulating substrate and interconnected by drive signal buses with an electrically insulative polymerized layer disposed over the thin film circuit elements and drive signal buses, and each display element including a plural level electrode disposed on the insulating substrate and extending over the insulative polymerized layer, with an electroluminescent phosphor layer disposed over the entire panel area in contact with the electrodes, which method comprises:

(a) depositing the interconnected thin film circuit elements, signal buses and first level electrodes in sequence as an X-Y array on the planar insulating substrate;

(b) applying a relatively thick insulative photo-polymerized layer over the entire panel side on which the thin film circuit elements are disposed;

(c) directing photo-radiation through the substrate to photo-polymerize exposed areas of the photo-polymerizable layer which are not shielded by the opaque first level electrode and by the opaque thin film circuitry and buses, with the photo-polymerized area of the layer against the first level electrode at the bottom surface of the photo-polymerizable layer exceeding the area that is photo-polymerized at the upper surface of the layer so that a generally inverted conic unpolymerized layer portion extends above each first level electrode;

(d) disposing an opaque photomask over the layer aligned with each first level electrode, with the opaque photomask area exceeding the first level electrode area and approximating the area of the unexposed upper surface above the first level electrode;

(e) exposing the layer to photo-radiation directed from above the photomask to photo-polymerize the unexposed portion of the layer except for the area covered by the photomask;

(f) removing unpolymerized portions of the layer;

(g) vacuum depositing conductive metal electrodes over the insulative photo-polymerized layer to form the second level electrode portions and the connecting electrode portions which extend down to and contact the first level electrode portion; and

(h) depositing an electroluminescent phosphor layer on the conductive metal electrodes and connecting electrode portions and onto the insulative photo-polymerized layer between the spaced electrode portions.

The electroluminescent display panels thus have a structure in which the individual electrodes are extended over a substantial area of the total display panel. Desirably, the individual electrodes comprise a multi-level electrode with a first level electrode portion disposed on the insulative substrate, and with a second level electrode portion disposed on the insulating polymerized layer, with a connecting electrode portion extending between the first and second level electrode portions.

The effective lit area and brightness of the panel can thus be greatly increased, with a recent panel lit area being greater than about seventy percent of the panel area.

In order that the invention can be more clearly understood, convenient embodiments thereof will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of electroluminescent display panel of the present invention connected to the drive means;

Figure 2 is a cross-sectional view through a portion of the panel which illustrates the multi-level electrode structure of the panel of the present invention,

Figure 3 is an enlarged schematic representation of the display element array pattern illustrating the thin film circuitry of the display panel;

Figure 4 is a schematic illustration of a fabrication technique utilized in fabricating the panel of the present invention;

Figure 5*a* is an illustration of the edge structure of the photo-polymerized layer when fabricated using prior art technique;

Figure 5*b* is an illustration of the edge pattern of the photo-polymerized layer when fabricating using the method of the present invention as illustrated in Figure 4.

The electroluminescent display panel 10 is seen schematically in Figure 1 connected to operative drive circuitry. The display panel 10 comprises a planar insulating substrate 12 upon which are disposed thin film circuit elements 14 which are arrayed as X-Y rows and columns of individually addressible and controllable display elements which are interconnected by addressing and drive signal buses 16, 18 and 20. The basic thin film transistor circuit and method of fabrication is set forth in the copending application discussed above. Each display element as seen more clearly in Figure 3 includes a switching transistor T_1, a drive transistor or power transistor T_2, and a storage capacitor C_s. The video signal impressed on the X_i bus from analog video register 22 and line write scan means 24 to which the video signal is fed through switching transistor T_1 when the appropriate addressing signal is present on switching bus Y_j turning in transistor T_1 to charge the storage capacitor C_s to a voltage level which is indicative of the video signal. The switch blues Y_j are individually connected to vertical scan driver 26. A high frequency power supply 28 is connected to a common light transmissive, top electrode above the electroluminescent phosphor to actuate the phosphor. When all of the capacitors C_s in a given line are charged with the video signal a gate signal is applied to the gate of transistor T_2 turning T_2 on, and permitting application of the high frequency display power signal across the electrodes and the EL phosphor layer.

The thin film transistor circuit elements T_1, T_2, C_s, and the information signal, switching signal and power signal buses are deposited in successive stages as thin films of the respective materials with appropriate insulation layers provided thereover upon the substrate 12. A first level electrode portion 30 is deposited directly upon the insulating substrate 12 during one of the metal vapor deposition stages. The partially fabricated panel is thereafter removed from the vacuum system and a photo-polymerizable layer is pressed over the entire panel area. The applied photo-polymerizable layer is an insulating material which can be polymerized in place upon exposure to the photo-radiation. A suitable photoresist is "Riston", a DuPont trademarked material. This polymerized insulator layer 32 is a relatively thick layer typically being about 1 mil in thickness to effectively insulate the thin film circuit elements and the various buses from the electroluminescent phosphor layer 34 which covers the entire panel. It has been the practice to merely contact the first level electrode 30 with the phosphor material. Thus, only that portion of the electroluminescent phosphor layer directly above the electrode deposited on the substrate was actually excited to luminescence. A common top electrode 36, which is light transmissive, is disposed atop the top of the phosphor layer 34. This common electrode 36 is connected to the power supply 28. A glass face plate 42 may be provided over top electrode 36. The insulating polymer layer 32 covers all of the thin film circuit components except the first level electrodes 30. Apertures are provided in this polymer insulating layer 32 by a further resist technique described hereafter to expose the first level electrodes. In these cross-sectional views, the relative dimensions of the layers is greatly exaggerated for ease of description.

In order to further expand the active area of the electroluminescent phosphor a second level electrode 38 is deposited atop the polymer insulator layer 32. This second level electrode 38 is generally planar and parallel to the first level electrode. A connecting electrode portion 40 electrically connecting the first level electrode and the second elevel electrode is deposited along the slope of the polymer insulator layer 32 the edges of the aperture which is opened in the polymer insulator layer against the electrode 30. The first level electrode portion 30 is a generally rectangular pad which occupied a portion of the area of each unit display element. The apertures which are formed in the polymer insulator layer 32 are rectangular and have a generally inverted cone cross section, i.e., the aperture area is smaller at surface of the first level electrode 30 than it is at the top surface of the layer 32. A gradual inward sloped edge is thus formed in layer 32 at each said aperture above each electrode 30. The electroluminescent phosphor layer 34 is then deposited over the entire display panel in contact with the first level electrode 30, the second level electrode 38 and the connecting electrode portion 40, so that a greatly increased area of phosphor for a given display element is activated. This greatly improves the brightness level of the panel. The individual electrodes can thus cover a substantial portion of the total area of the display panel, with the only area of non-coverage being the requisite spacing between adjacent edges of the individual electrodes. In achieving about seventy percent lit area the spacing between electrodes was about 8 mils, this spacing can be reduced to about 2-3 mils to further increase the electrode area and the lit area of the panel.

The fabrication of the multi-level electrode structure in the display panel of the present invention involves careful attention in deposition of the connecting electrode portion 40 to ensure a continuous, large area electrode made up of the first level and second level and connecting electrode portions. The thickness of the photo-polymerizable insulating layer 32 presents a problem in that when the photo-polymerizable material is exposed to photo-radiation with a mask imposed over the first electrode area when the apertures are formed over the electrodes 30 an edge effect is produced at the edge of the mask due to diffraction or scattering of the photo-radiation to produce what after developing of the unexposed area and forming of the aperture 44 is an overhang of polymerized material at the upper surface of layer 32 as seen in Figure *5a*. The formed aperture 44 has a smaller area at the upper surface of layer 32 than at the bottom surface. This overhang of photo-polymerized insulating material is undesirable in that it impedes deposition of an effective connecting electrode portion 40. This is because the metal layer which is vacuum deposited as the connecting electrode portion 40 is done by a line of slight vacuum deposition, and the overhang of photo-polymerized material prevents deposition of the metal in this overhang area. The edge of the photo-polymerized insulator adjacent the first level electrode desirably has a gradual slope as seen in Figure *5b* where the aperture 46 has the desired sloped edges with the aperture area at the upper surface of layer 32 exceeding the aperture area at the bottom surface to thereby permit line of sight metal deposition on these edges. The second level electrode 38 is vapor deposited at the same time as connecting electrode portion 40 atop the top planar surface of the photo-polymer insulator layer 32. The individual electrodes are preferably formed of aluminium which is vacuum deposited to a thickness of about 1500 Angstroms in forming such electrodes. The first level portion 30 may be thicker than the second level portion 38 and the connecting portion 40 because during deposition of the second level and connecting portions the deposited metal also covers the already deposited first level electrode. This ensures good contact between each electrode portion.

A technique for ensuring that the slope of the edge of the insulator layer is as seen in Figure *5b* is illustrated by a method which can be best understood by reference to Figure 4. The photo-radiation typically ultra-violet used for selectively polymerizing layer 32 is first directed through the substrate 12 past the opaque first level electrode 30 itself as well as past the opaque thin film circuit portions. The photo-radiation directed through the substrate passes around the rectangular first level electrode 30 and photo-polymerizes the layer 32 with an edge profile about the electrode which approximates that seen in Fig. *5b*. The bottom portion of layer 32 is fully polymerized while the upper portions of layer 32 above the edge of electrode 30 are unpolymerized so that when the layer 32 is developed to remove the unexposed areas the aperture 46 formed has a smaller area at the bottom than at the top surface with a gradual sloped edge provided. The sloped edge is thus available for direct line of sight metal deposition to lay down a continuous connecting electrode portion on this sloped edge.

After the exposure through the substrate 12 to establish the desired aperture shape, and before developing the layer to form the aperture, a second photo-exposure is carried out from the conventional direction, i.e., from the top surface of the layer 32. An opaque photomask is aligned over the first level electrode areas. The size or area of the opaque mask aligned above the first level electrode is greater than the first level electrode area. This is to prevent further exposure of the upper portion of layer 32 at the edges about the electrode 30 while at the same time exposing the layer 32 above the rest of the panel which were blocked by the opaque buses and the thin film circuitry when the photo-radiation was directed through the substrate. The layer 32 is then effectively polymerized at all areas except the area over the electrode 30.

The plural electrode level panel structure of the present invention provides a significant increase in the lit area of the phosphor layer and this increase in area produces an increased brightness panel. The brightness of the panel is further improved due to the fact that the second level portion of the electrode is atop the relatively thick insulating layer over the thin film circuitry. The phosphor layer between the second level electrode portion and the top electrode is less than between the first level electrode portion and the applied voltage across the thinner phosphor layer produces greater luminescent output from the phosphor.

WHAT WE CLAIM IS:—

1. An electroluminescent display panel which comprises an X-Y array of display elements each of which comprises integral thin film transistor switching and control circuit elements disposed on an insulative panel substrate and interconnected by drive signal buses, and each display element including an individual electrode disposed on the substrate, with an electrically insulative polymerized layer over the thin film elements and the signal buses, with the electroluminescent phosphor disposed over the entire panel area in contact with the individual electrodes and over the insulative

polymerized layer, the individual electrodes extending from the insulative substrate and covering a substantial portion of the insulative polymerized layer.

2. A display panel according to claim 1, wherein the individual electrode is a multilevel electrode with a first level electrode portion disposed on the insulative substative, a second level electrode portion disposed on the insulative polymerized layer, and a connecting electrode portion extending between the first and second level electrode portions.

3. A display panel according to claim 1 or 2, wherein the individual electrodes are closely spaced from each other and cover a substantial portion of the total display panel.

4. A display panel according to claim 1, 2, or 3, wherein the individual electrodes are aluminum deposited to a thickness of about 1500, Angstroms.

5. A method of fabricating an electroluminescent display panel comprising a thin planar insulating substrate having an X-Y array of display elements thereon each of which display elements include integral thin film transistor switching and control circuit elements disposed on the insulating substrate and interconnected by drive signal buses with an electrically insulative polymerized layer disposed over the thin film circuit elements and drive signal buses, and each display element including a plural level electrode disposed on the insulating substrate and extending over the insulative polymerized layer, with an electroluminescent phosphor layer disposed over the entire panel area in contact with the electrodes, which method comprises:

(a) depositing the interconnected thin film circuit elements, signal buses and first level electrodes in sequence as an X-Y array on the planar insulating substrate;

(b) applying a relatively thick insulative photo-polymerized layer over the entire panel side on which the thin film circuit elements are disposed;

(c) directing photo-radiation through the substrate to photo-polymerize exposed areas of the photo-polymerizable layer which are not shielded by the opaque first level electrode and by the opaque thin film circuitry and buses, with the photo-polymerized area of the layer against the first level electrode at the bottom surface of the photo-polymerizable layer exceeding the area that is photo-polymerized at the upper surface of the layer so that a generall inverted conic unpolymerized layer portion extends above each first level electrode;

(d) disposing an opaque photomask over the layer aligned with each first level electrode, with the opaque photomask area exceeding the first level electrode area and approximating the area of the unexposed upper surface above the first level electrode;

(e) exposing the layer to photo-radiation directed from above the photomask to photo-polymerize the unexposed portion of the layer except for the area covered by the photomask;

(f) removing unpolymerized portions of the layer;

(g) vacuum depositing conductive metal electrodes over the insulative photo-polymerized layer to form the second level electrode portions and the connecting electrode portions which extend down to and contact the first level electrode portion; and

(h) depositing an electroluminescent phosphor layer on the conductive metal electrodes and connecting electrode portions and onto the insulative photo-polymerized layer between the spaced electrode portions.

6. A method of fabricating an electroluminescent display panel substantially as described herein with particular reference to Figs. 4 and 5b of the accompanying drawings.

7. Electroluminescent display panels when made by a method according to claim 5 or 6.

8. Electroluminescent display panels substantially as described herein with particular reference to Figs. 1 to 3 of the accompanying drawings.

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1567623 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

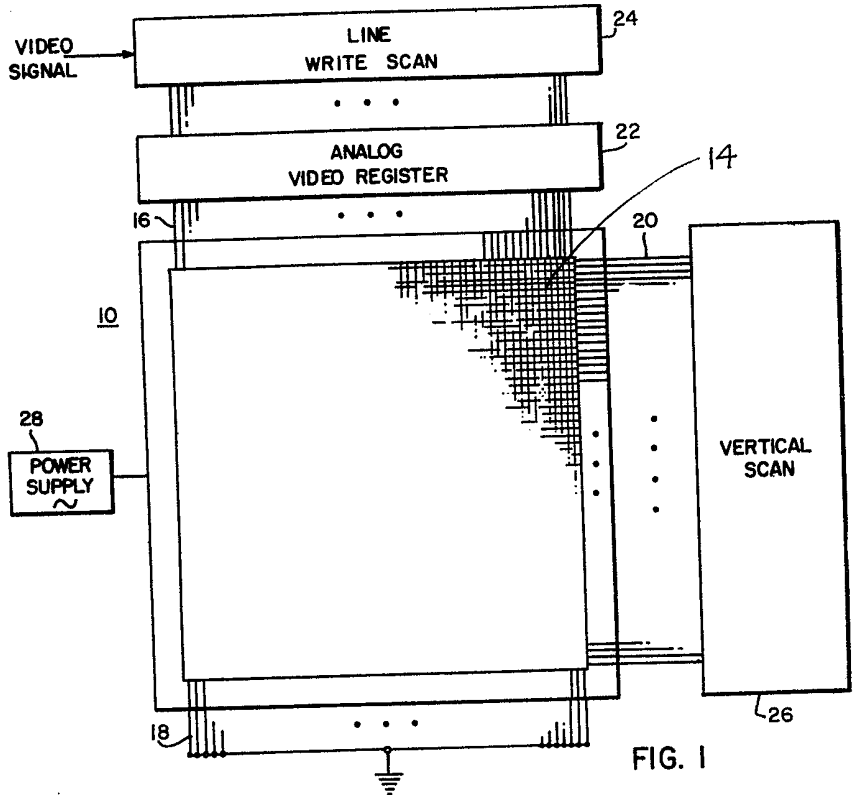

FIG. 1

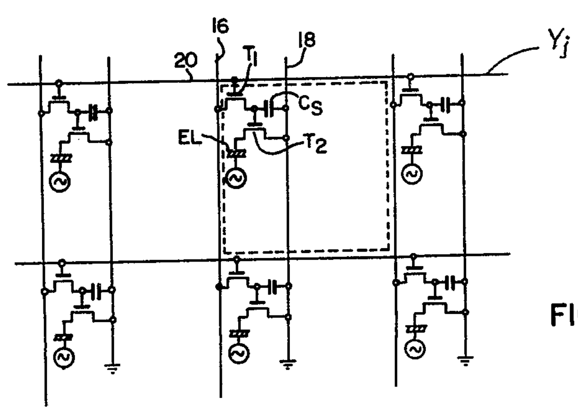

FIG. 3

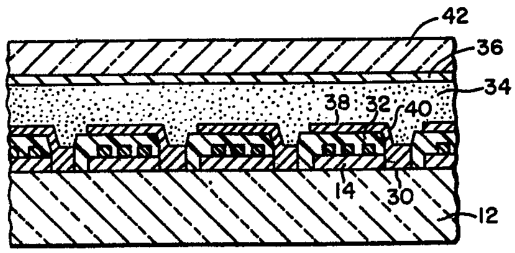

FIG. 2

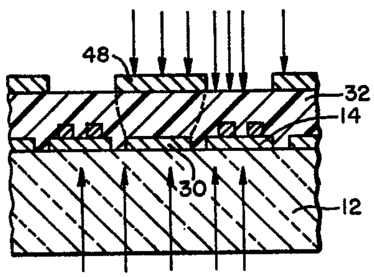

FIG. 4

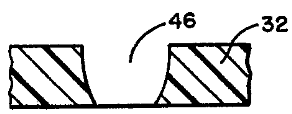

FIG. 5B

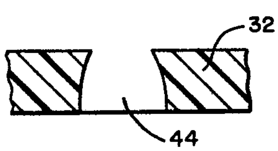

FIG. 5A