Oct. 25, 1966 L. E. GREENE 3,281,619

ELECTROLUMINESCENT DISPLAY DEVICE WITH EDGE TERMINATED CONTACTS OVERLYING AN APERTURED LOW DIELECTRIC INSULATOR SHEET

Filed March 27, 1963 2 Sheets-Sheet 1

Fig. 1.

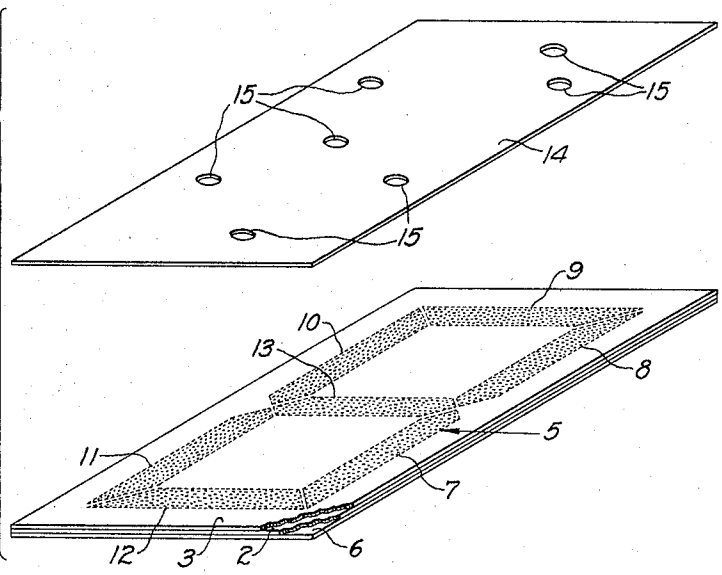


Fig. 2.

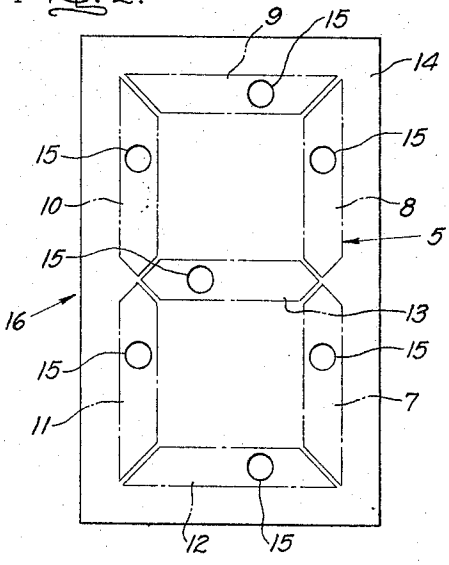


Fig. 3.

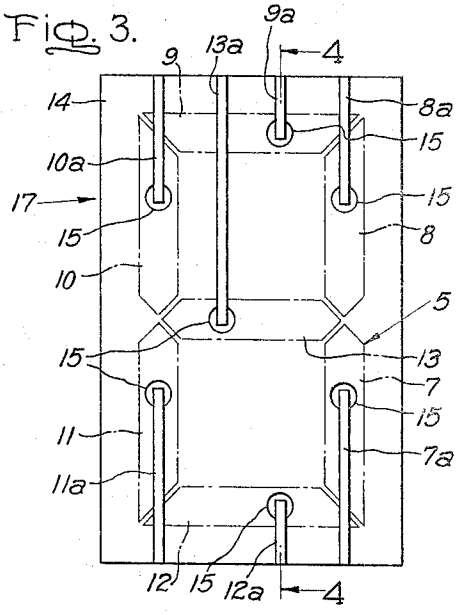
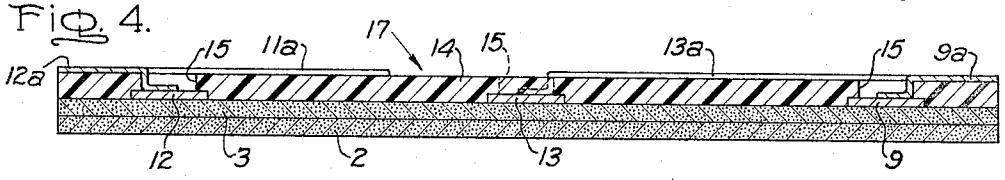


Fig. 4.



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Fig. 5.

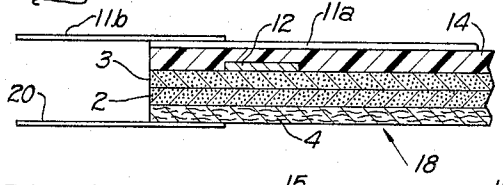


Fig. 6.

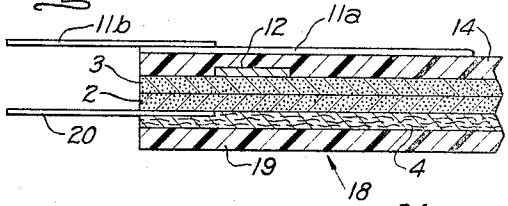


Fig. 7.

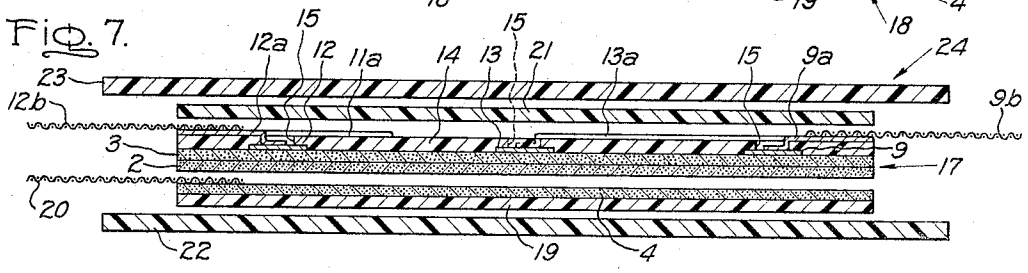


Fig. 8.

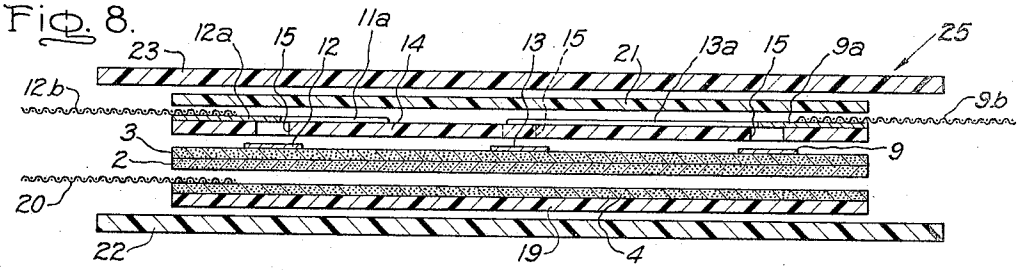
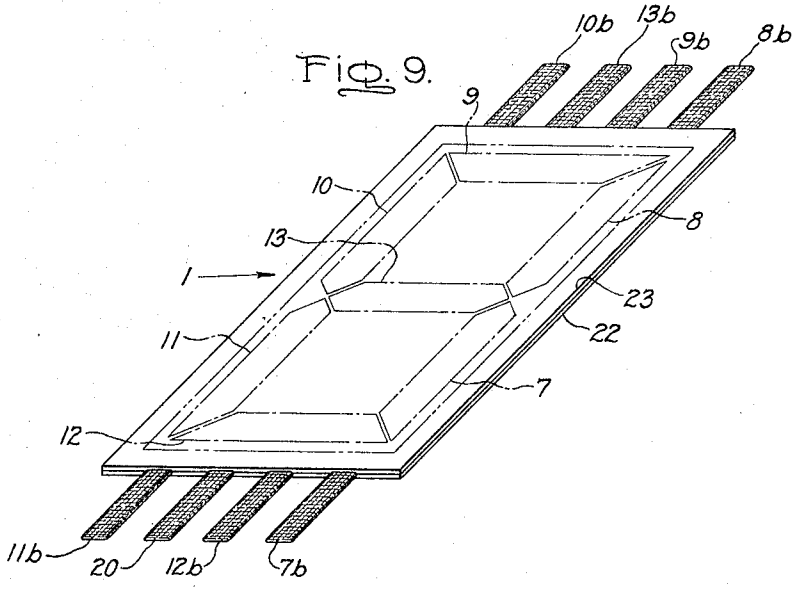


Fig. 9.



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ELECTROLUMINESCENT DISPLAY DEVICE WITH EDGE TERMINATED CONTACTS OVERLYING AN APERTURED LOW DIELECTRIC INSULATOR SHEET

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6 Claims. (Cl. 313—108)

This invention relates in general to electroluminescent cells or lamps and, more particularly, to an electroluminescent cell or lamp in the form of an electroluminescent display device or panel such as a digital display or read-out device, and to a method of making such a device.

Electroluminescent cells or lamps in the form of display devices or panels such as digital display or read-out devices are well known in themselves at present as disclosed, for example, in U.S. Patent 2,922,993, E. A. Sack, Jr. Such devices comprise in general a layer of a suitable electroluminescent phosphor sandwiched between a pair of electrically conductive layers one of which is light-transmitting and the other of which is subdivided into a plurality of discrete electrode sections of predetermined shape and array such that, upon selective application of an A.C. potential across the light-transmitting electrode layer and one or more of the discrete electrode sections, the areas of the phosphor layer overlying the discrete electrode sections selectively energized are caused to luminesce, thereby producing the desired luminous pattern from the device such as, for example, a digit or a letter.

While the current supply leads to the individual electrode sections of such electroluminescent display devices or panels may be terminated through the back or non-viewing side of the display panel, it is preferable that they be terminated at the peripheral edges or rim of the panel, since with such a method of termination the display panel can be desirably kept to a minimum thickness and also free of projecting contact terminals at the back side. However, the necessity for keeping the individual leads to the individual electrode sections of such edge contact terminated type electroluminescent display panels from crossing and so electrically contacting any of the other leads or electrode sections of the panel has resulted, in prior type edge contact terminated electroluminescent display panels as heretofore generally constructed, not only in a loss of available display area for a given panel surface area, but also in a loss in definition of the illuminated display pattern owing to the necessity for spacing certain ones of the electrode sections sufficiently far apart to permit passage therebetween of a lead without touching and electrically contacting such electrodes. Moreover, the design and manufacture of such edge contact terminated type electroluminescent display panels heretofore has been complicated by the necessity for incorporating therein some provision for insuring that the leads to the electrode sections will not themselves capacitively couple to the light-transmitting electrode upon application of A.C. potential thereacross, with resulting undesired light emission from the portions of the phosphor layer directly overlying the energized lead or leads such as would normally detract from the appearance of the illuminated display pattern.

It is an object of the invention, therefore, to provide a novel form of electroluminescent display device or panel of the edge contact terminated type which permits maximum utilization of the available surface area thereof for display electrode purposes and affords improved definition of the illuminated display pattern or patterns produced by the device.

Another object of the invention is to provide an electroluminescent display device or panel of the edge contact terminated type having a simplified structural arrangement, easily incorporable into the device during manufacture, for preventing the current supply leads to the discrete electrode sections of the device from capacitively coupling to the light-transmitting electrode thereof during operation.

A further object of the invention is to provide a novel method of making an electroluminescent display device or panel of the edge contact terminated type.

Briefly stated, in accordance with one aspect of the invention, the current supply leads which are electrically connected to respective ones of the segmented electrode sections of an electroluminescent display device of the edge contact terminated type are electrically insulated from the phosphor layer, and from the others of said electrode sections, by an intervening preformed insulator sheet of an organic thermoplastic material of low dielectric constant or permittivity having apertures underlying respective ones of the electrode sections, through which apertures the current supply leads extend into contact with respective ones of the electrode sections to electrically connect therewith. Because of its low permittivity, the insulator sheet also serves to effectively prevent the portions of an energized current supply lead, other than those portions which are shielded by an overlying energized electrode section, from capacitively coupling to the light-transmitting electrode of the device and so causing undesired luminescence of the portions of the phosphor layer overlying such unshielded lead portions.

In accordance with a further aspect of the invention, the segmented electrode sections of an electroluminescent display device are first applied to one side of a phosphor-containing sheet, following which a preformed insulator sheet of a low dielectric constant organic thermoplastic material is then applied over the segmented electrode side of the phosphor-containing sheet as by laminating it thereto, the insulator sheet having small apertures registering with respective ones of the electrode sections. Current supply leads for the respective electrode sections are then applied over the insulator sheet as by a silk-screen coating process to extend from the edge thereof to respective ones of the apertures therein and through the apertures into electrical contact with the underlying electrode sections. The assembly thus formed is then laminated together with a light-transmitting electrically conductive layer on the other side of the phosphor-containing sheet and preferably, in addition, between suitable water vapor barrier layers and outer thermoplastic encapsulating sheets, such as are conventionally employed in organic type electroluminescent cells, to thereby form the completed electroluminescent display device or panel.

Further objects and advantages of the invention will appear from the following detailed description of species thereof and from the accompanying drawing.

In the drawing, FIG. 1 is an exploded perspective view illustrating one of the initial steps in the manufacture of an electroluminescent display device according to the invention wherein an apertured insulator sheet is assembled together with a phosphor-bearing sheet so as to overlie a segmented black electrode layer thereon.

FIG. 2 is a plan view of the assembled insulator sheet and segmented electrode-carrying phosphor layer components shown in FIG. 1.

FIG. 3 is a plan view illustrating a subsequent step in the manufacture of the electroluminescent display device according to one method comprising my invention wherein current supply leads are coated or printed on the apertured insulator sheet of the assembly shown in FIG. 2 so as to electrically connect with respective ones of the segmented electrode sections thereof.

FIG. 4 is a sectional view of the assembly shown in FIG. 3 on the line 4—4 thereof.

FIG. 5 is a fragmentary sectional view of an electroluminescent display device according to one form of the invention.

FIG. 6 is a similar fragmentary sectional view of an electroluminescent display device according to another form of the invention.

FIG. 7 is a sectional view showing the lay-up assembly of component elements which is employed in making an encapsulated type of electroluminescent display device by one method according to the invention.

FIG. 8 is a similar sectional view showing the lay-up assembly of component elements which is employed in making an encapsulated electroluminescent display device by another method according to the invention, and

FIG. 9 is a perspective view of a completed electroluminescent display device comprising my invention, as viewed from the back or non-light-emitting side thereof.

Referring to the drawing, the invention is therein illustrated, for purposes of representation, as applied to an electroluminescent display panel in the form of a digital display device or read-out lamp **1** adapted to selectively display, in a luminous pattern, any digit or numeral from 0 to 9, as desired. It should be understood, however, that the invention is applicable as well to various other forms of electroluminescent display devices for the selective display of various other types or forms of indicia, characters, patterns or designs.

As shown in FIGS. 5 and 6, the electroluminescent display device **1** according to the invention is comprised in general of an electrically active assembly comprising a thin electroluminescent phosphor layer **2**, and preferably in addition a thin contiguous insulating layer **3** of high dielectric constant material, sandwiched between a light-transmitting electrically conductive front electrode layer **4** and a segmented back electrode layer **5** which is disposed next to the insulating layer **3**, where such is employed. The phosphor layer **2** is constituted by a self-supporting sheet or film comprising a conventional type electroluminescent phosphor such as, for example, zinc sulfide-zinc oxide combined with suitable activators such as copper, manganese, lead or silver, dispersed in an organic polymeric matrix material. Examples of suitable organic polymeric matrices are cellulose nitrate, polyacrylate, methacrylates, polyvinylchlorides, cellulose acetate, alkyd resins, epoxy cements, and polymers of triallylcyanurates, to which may be added modifying substances or plasticizers such as camphor, dioctylphthalate, tricresylphosphate and similar materials. However, plasticized cyanoethyl polyglucosides such as cyanoethyl cellulose plasticized with cyanoethylphthalate, as described and claimed in copending application Serial No. 701,907, Jaffe, filed December 10, 1957, now U.S. Patent 3,238,407, and U.S. Patent 2,951,865, Jaffe et al., dated September 6, 1960, both assigned to the same assignee as the present invention, are preferred organic matrices which form a dense tough film of high dielectric constant and good mechanical and thermal stability.

In accordance with the invention, the phosphor-containing sheet **2** is formed by applying a coating of a suspension of the electroluminescent phosphor in a solution of the organic polymeric matrix material to one side of a temporary support or release sheet **6** comprised of a thin flexible material such as, for example, either polyethylene terephthalate or polytetrafluoroethylene, which are commonly known as Mylar and Teflon, respectively. Materials such as Mylar and Teflon are chosen for the temporary support sheet **6** because of their ability to be easily removed from layers of organic polymeric materials of the type such as are commonly employed as matrix materials for the phosphor layer **2**. The temporary support sheet **6** alternatively may be composed of other thermoplastic materials or treated papers having the desirable release properties of Mylar and Teflon. The phosphor coating suspension may be applied to the temporary support sheet **6** by means of a conventional type doctor blade coating device, or it may be deposited by spraying it only the support sheet. The coating suspension is applied to the support sheet at the proper wet coating thickness required to produce a final dried phosphor layer **2** of the desired thickness which, in general, may be in the range of 20–30 microns or thereabouts. After drying of the phosphor coating **2**, a thin layer **3** of a high dielectric constant insulating material such as barium titanate, also dispersed in a high dielectric constant organic polymeric matrix material such as the preferred cyanoethyl cellulose solution referred to above, may then be applied over the phosphor layer **2**, as by spraying or through the use of a doctor blade coating device. The dried thin insulating layer **3**, which also may be of a thickness in the range of 20 to 30 microns or so, functions in the completed electroluminescent display device **1** to prevent electrical shorting between the conductive layers **4** and **5**.

Applied onto the dried insulating layer **3**, or onto the dried phosphor-bearing layer **2** in the case where the insulating layer **3** is not employed, is the segmented back electrode layer **5** which comprises an array of discrete electrically conductive electrode sections or areas **7** to **13**, respectively. These electrode sections **7** to **13** correspond in shape and array to the particular pattern of illumination desired when an A.C. potential is applied across the front electrode **4** and one or more of the back electrode sections **7** to **13**. In the case of the particular digital display or read-out device illustrated, the segmented electrode **5** is composed of seven bar-shaped electrode sections or areas **7** to **13** arranged in two side-by-side substantially square patterns having a common side so as to delineate the block number eight located more or less centrally within and longitudinally aligned with the rectangularly shaped display area of the device. As shown, the electrode sections **7** to **13** are spaced apart a slight distance at the points where they meet, for example, a distance of around 1 mil, so as to be electrically insulated from each other. By applying an A.C. potential across the front electrode **4** and preselected ones of the back electrode sections **7** to **13**, in the manner such as disclosed for example in the aforementioned U.S. Patent 2,922,993, any digit from 0 to 9 may be made to light up on the display panel.

The discrete electrode sections **7** to **13** may be applied in the desired pattern over the insulating layer **3**, or over the phosphor-bearing layer **2** where the insulating layer **3** is not employed, by any suitable process, as by a silk screen printing process, preferably employing a conducting silver silk screen ink or paint for the electrode sections. Any suitable conducting silver or other type silk screen ink or paint such as is commercially available at present may be employed for this purpose such as, for example, that known as Silpaint No. LO5–1162 or LO6–1150 made by the Industrial Products Division of Handy & Harman of New York, N.Y., or Silver Composition No. 7095 of the Group 4 series of conductive liquid silver preparations made by the Electrochemicals Department of the E. I. du Pont de Nemours & Company of Wilmington, Delaware. Alternatively, the back electrode sections **7** to **13** may be comprised of some form of conductive paint, paste, or similar conductive material which may be sprayed, rolled, or otherwise applied onto the insulating layer **3** as through a masking screen so as to form the array of discrete electrode sections. As another alternative, the electrode sections **7** to **13** may be formed by well known vacuum deposition methods wherein aluminum or other vaporizable electrically conductive materials such as, for example, tin oxide, are vacuum deposited onto the insulator layer **3** through a masking screen. Also, aluminum foil or similar conducting foil of shapes

corresponding to the individual electrode sections **7** to **13** may be secured to the insulating layer **3** by means of a suitable conducting cement. After application of the segmented back electrode layer **5** over the insulating layer **3**, the entire assembly may be dried if necessary, following which the flexible temporary support sheet **6** may then be peeled or removed from the remainder of the assembly, leaving the assembly of the phosphor and insulating layers **2** and **3** with the back electrode layer **5** thereon. This assembly is sufficiently self-supporting, because of the self-supporting character of the organic polymeric materials employed for the matrices of the phosphor and insulating layers **2** and **3** to permit the subsequent handling and processing of the assembly without any danger of it disintegrating or breaking apart. For such reason also, the removal of the temporary support or release sheet **6** from the assembly may, if desired, be performed before the application of the back electrode to the phosphor and insulating layers instead of after such electrode application.

In accordance with the invention, a thin preformed electrically insulating layer or separator sheet **14** of a suitable organic thermoplastic material having a low dielectric constant or permittivity is applied over the insulating layer **3** and the segmented back electrode layer **5** thereon. Examples of organic thermoplastic materials of low permittivity which may be suitably employed for the insulator sheet **14** are polytetrafluoroethylene, nylon, polyethylene, and polychlorotrifluoroethylene. For the purposes of the invention, the plastic insulator sheet **14**, which because of its low permittivity characteristic need only to be around 1 to 3 mils or so in thickness, is formed with a plurality of small apertures **15** which correspond in number to, and overlie or register with respective ones of the back electrode sections **7** to **13** when the insulator sheet is properly positioned over and applied to the insulator layer **3**, as shown in FIG. 2. The electrical connection of the current supply leads for the individual electrode sections **7** to **13** is made through these apertures **15** in the insulator sheet **14**.

According to the preferred method of making the electroluminescent display device **1** in accordance with the invention, the perforated plastic insulator sheet **14** is laminated to the assembly of the phosphor layer **2** and back electrode layer **5**, with or without the intervening high dielectric constant insulating layer **3**, to form a back electrode-phosphor layer subassembly or prelaminate **16**, as shown in FIG. 2. The laminating of the apertured plastic insulator sheet **14** to the assembly of the phosphor and insulating layers **2** and **3** and back electrode layer **5** may be carried out, under heat and pressure, in any suitable laminating press. Applied to the plastic insulator sheet **14** of this prelaminate **16** are a plurality of electrically conductive current-supply leads **7***a* to **13***a* (FIG. 3) for the respective electrode sections **7** to **13**. The electrically conductive leads **7***a* to **13***a* correspond in number to the electrode sections **7** to **13** and, as shown in FIG. 3, they extend from the edge of the insulator sheet **14** inwardly thereof to and through the apertures **15** therein into electrical contact with respective ones of the electrode sections. Although the leads **7***a* to **13***a* are preferably terminated either at the opposite edges of the rectangularly-shaped subassembly **16** such as at the shorter edges thereof as shown in FIG. 3, or entirely at a single one of the edges thereof such as at one of its shorter edges, they may be terminated instead at more than two of its edges such as at all four of its edges, as desired. In accordance with the preferred method of making the electroluminescent display device **1**, the electrically conductive leads **7***a* to **13***a* are applied to the plastic insulator sheet **14** of the subassembly or prelaminate **16** in the form of a printed circuit comprised of stripe-shaped coatings of suitable electrically conductive material which may be deposited onto the insulator sheet by any of the metal deposition procedures described above for the application of the electrode sections **7** to **13** onto the insulating layer **3**. Preferably, however, the electrically conductive leads **7***a* to **13***a* are applied to the insulator sheet **14** by a conventional silk screen process, employing a suitable electrically conductive silver or other type silk-screen ink such as, for example, that commercially known as Silpaint No. 1250–04 or Silpaint No. LO1–1054, made by the Industrial Products Division of Handy & Harman, of New York, N.Y. The deposition of the electrically conducting leads **7***a* to **13***a* on the insulating sheet **14** of the prelaminate **16** completes the fabrication of a combination phosphor layer and back electrode unitary subassembly **17** as shown in FIGS. 3 and 4, which is then combined with the other elements of the electroluminescent display device to form the final completed device.

To this end, there is applied over the phosphor layer side **2** of the subassembly **17** a light-transmitting or transparent electrically conductive front electrode layer **4** to form therewith the electrically active assembly **18** of the electroluminescent display device **1**, as shown in FIGS. 5 and 6. The electrically conductive layer **4** may be in the form, for example, of a sheet of electrically conductive glass paper such as commercially available micro-fiber glass paper around 0.001 inch thick which has been rendered electrically conductive in any suitable manner, as by dipping the paper in a solution of a suitable metal salt such as indium basic trifluoroacetate and subsequently drying and baking the paper at elevated temperatures to provide a conductive coating on the surface portion of the constituent glass fibers. For a more complete description of the materials and processes that may be employed in providing such a conductive glass paper, reference may be made to U.S. Patent 2,849,339, Jaffe, issued August 26, 1958, and assigned to the assignee of the present invention. The electrically conductive glass paper forming the front electrode **4** may be laminated to the phosphor layer **2** of the subassembly **17** under heat and pressure so as to form, with the other layers, the electroluminescent panel subassembly **18**. The laminating of the conductive glass paper to the subassembly **17** may be carried out in any suitable laminating press. Suitable selection of the temperature and pressure of the laminating operation will result in a tight bond between the glass paper and electroluminescent phosphor layer **2** of the subassembly **17**. As shown in FIG. 6, the electrically conductive glass paper forming the front electrode layer **4** may, if desired, be prelaminated to a reinforcing light-transmitting organic thermoplastic sheet **19** prior to its lamination to the subassembly **17**, as described and claimed in copending U.S. application Serial No. 137,924, Longfellow, filed September 13, 1961, now U.S. Patent 3,226,272, and assigned to the assignee of the present invention. The reinforcing plastic sheet **19** is preferably composed of a thermoplastic material which is of low water-vapor permeability and exhibits hydrophilic properties, i.e., has an affinity for water. Polyamide condensation products such as nylon **6**, **6**, or nylon **6** such as that known as "Caplene," have been found to be particularly effective as hydrophillic materials for the thermoplastic layer **19**.

In accordance with the preferred form of the invention, however, the front electrode layer **4** is composed of a light-transmitting electrically conductive lacquer such as, for example, that described and claimed in copending U.S. application Serial No. 189,095, Jaffe et al., filed April 20, 1962, and assigned to the assignee of the present invention, and comprising a dispersion of electrically conductive light-transmitting particulate material, such as indium oxide or pulverized electrically conductive glass paper as described hereinabove, in a light-transmitting organic plastic matrix material such as, for example, that employed as the matrix material for the phosphor and insulating layers **2** and **2**. The conductive lacquer layer may be directly applied to the phosphor layer **2** of the subassem-

bly **17** in the form of a coating **4** (FIG. 5), as by means of a conventional type doctor blade coating device, for example. Preferably, however, the conductive lacquer layer is first coated onto one side of a light-transmitting organic thermoplastic sheet **19** such as described hereinabove, which is then laminated under heat and pressure to the subassembly **17** with the conductive lacquer coating **4** next to the phosphor layer **2**.

The electrically active assembly **18** as described above may itself be utilized as an electroluminescent display device, in which case it is provided with terminal contact members **20**, and **7***b* to **13***b* only one of which (**11***b*) is shown in FIGS. 5 and 6, which contact members are connected, respectively, to the front electrode layer **4** and to the respective leads **7***a* to **13***a* from the individual electrode sections **7** to **13** comprising the back electrode layer **5**, for the purpose of supplying an A.C. potential to the two electrode layers. The terminal contact members, which may consist of wires or ribbons or wire cloth, of copper or phosphor bronze, for example, are electrically connected to the front electrode layer **4** and to the leads **7***a* to **13***a* from the back electrode layer **5** in any suitable manner as, for example, by being laminated thereto during the lamination of the electrode layer **4** to the subassembly **17**, or by being suitably attached thereto as by the use of a commercially available silver-loaded electrically conducting epoxy cement. However, since the light output of an electroluminescent cell deteriorates rapidly on exposure to water vapor, such as the moisture normally present in the atmosphere, it is preferably to encapsulate the electrically active elements of the electroluminescent display device **1** according to the invention in a substantially vapor-tight enclosure and to also incorporate suitable water-vapor barrier layers therein. Accordingly, as shown in FIGS. 7 to 9, the electrically active elements **2**, **3**, **4** and **5** of the electroluminescent display device **1** according to the invention are preferably laminated, under heat and pressure in a suitable laminating press, between front and back water-vapor barrier layers **19** and **21**, and between outer encapsulating sheets **22** and **23** of light-transmitting thermoplastic material of low water-vapor permeability which overreach the margins of the electrically active elements **2**, **3**, **4** and **5** and barrier layers **19**, **21** and are sealed together around their marginal edges so as to completely encapsulate the said elements. The back water-vapor barrier layer **21** is preferably composed of the same light-transmitting hydrophilic organic thermoplastic material as the front barrier layer **19**, as described hereinbefore. However, because of its location on the non-light-emitting side of the device **1**, the back water-vapor barrier layer **21** need not be of light-transmitting character. For such reason, therefore, it may be made of opaque sheet materials, such as an aluminum or metal foil for example, which are much less permeable to water vapor than known light-transmitting organic thermoplastic materials. In such case, the water-vapor barrier **21** may consist of a composite double layer barrier member comprising an inner layer of a hydrophilic organic thermoplastic material such as described above for the layer **19** and an outer layer of an aluminum or other metal foil. The outer encapsulating sheets **22** and **23** are made of a light-transmitting organic thermoplastic material of tough and stable character and high impermeability to moisture and preferably flexible in nature. Among the materials which may be satisfactorily employed for this purpose are polyethylene, polytetrafluoroethylene, polychlorotrifluoroethylene, polystyrene, methyl methacrylate, polyvinylidene chloride, polyvinyl chloride, polycarbonate materials such as, for example, the reaction products of diphenyl carbonate and Bisphenol A, and polyethylene terephthalate. The material preferably employed for such purpose, however, consists of polychlorotrifluoroethylene film, known as Kel F, of approximately 0.005 inch thickness.

In accordance with the preferred method of making an electroluminescent display device **1** according to the invention having the electrically conductive elements **2**, **3**, **4** and **5** thereof enclosed within an outer encapsulating envelope, a phosphor layer and back electrode subassembly **17** such as shown in FIGS. 3 and 4 and not as yet provided with a light-transmitting front electrode layer **4**, or alternatively an electrically active subassembly **18** such as shown in FIGS. 5 or 6 and already provided with a light-transmitting front electrode layer **4**, is stacked together with the other component elements of the device to form a lay-up assembly **24** thereof as shown in FIG. 7, which lay-up assembly is then laminated together, under heat and pressure in a suitable laminating press, to thereby form the completed display device **1**. In making the lay-up assembly **24**, the front plastic vapor-barrier sheet **19** is first laid down on top the front plastic encapsulating sheet **22**. Where the front plastic vapor-barrier sheet **19** is itself provided with the light-transmitting front electrode layer **4** on one side thereof, as shown in FIG. 7, the sheet **19** in such case is laid down with its electrode layer side **4** facing upwardly. The contact terminal member **20**, which as stated above may suitably consist of a strip of copper or aluminum foil or ribbon, or wire cloth such as phosphor-bronze cloth for example, is then laid down in proper position on top the plastic vapor-barrier sheet **19** so as to project beyond the marginal edge of the front encapsulating sheet **22**, and it is then temporarily tacked in place to the plastic sheet **22** by suitably softening, as by means of a soldering iron for instance, a small localized area of the sheet **22** at a point preferably adjacent its outer marginal edge. The subassembly **17** or **18**, depending on whether the front electrode layer **4** is carried by the plastic vapor-barrier layer **19** or by the phosphor layer **2** of the subassembly, is then laid in place on top the plastic vapor-barrier sheet **19**, following which the terminal contact members **7***b* to **13***b*, which likewise may consist of strips of copper or aluminum foil or ribbon, or wire cloth such as phosphor-bronze cloth, are then laid down in proper position on top the respective electrically conductive leads **7***a* to **13***a* coated on the subassembly **17** or **18**, so as to project beyond the marginal edges of the front plastic encapsulating sheet **22** to which they are then temporarily tacked in place as in the manner employed for the terminal contact member **20**. The back vapor-barrier sheet **21** and the back encapsulating sheet **23** are then laid down in proper registered position on top the subassembly **17** or **18** to form the stacked lay-up assembly **24** as shown in FIG. 7, in readiness for the lamination together thereof.

The laminating of the lay-up assembly **24** may be carried out in any suitable laminating press which will subject the assembly to laminating heat and pressure, while under a vacuum for removing undesired gaseous materials therefrom. For such purpose, the lamination of the lay-up assembly **24** may be advantageously performed in the manner, and by the use of a hydrostatic laminating press such as described and claimed in Fridrich et al. Patent 2,945,976 or in Fridrich Patent 3,047,052, both assigned to the assignee of the present invention. The stacked lay-up assembly **24** is placed between the top and bottom press platens of the hydrostatic press, beneath a conformable diaphragm positioned between the press platens, the conformable diaphragm being constituted of a flexible gas-impervious sheet material such as soft annealed aluminum foil or polyethylene terephthalate film such as Mylar. Compressed fluid or air is admitted into the closed chamber of the press over the diaphragm therein to exert hydrostatic pressure on the stacked lay-up assembly, vacuum is supplied under the diaphragm to remove any trapped gases or moisture from the space therebelow and from the lay-up assembly **24** in the said space, and heat is then applied by suitable means to the stacked assembly **24**, as by passing an electric current through the metal foil diaphragm, in order to cause the plastic encapsulating sheets **22** and **23** to soften and seal together at their margins so as to encapsulate the lay-up assembly. During the lam-

inating process, the terminal contact members **20** and **7***b* to **13***b* become embedded in the marginal seal between the plastic sheets **22**, **23** and they are at the same time pressed into intimate contact with the front electrode layer **4** and with the electrically conductive leads **7***a* and **13***a* so as to make good electrical contact therewith.

Instead of prelaminating the perforated plastic insulator sheet **14** to the assembly of the phosphor layer **1** and back electrode layer **5** to form a back electrode-phosphor layer subassembly or prelaminate **16** as shown in FIG. 2 to which the electrically conductive leads **7***a* to **13***a* are then applied so as to produce the subassembly **17** for lamination together with the other components of the display device **1**, the perforated plastic insulator sheet **14** may be simply stacked together with the other elements of the display device in a lay-up assembly **25** (FIG. 8) similar to that shown in FIG. 7, with the apertures **15** of the plastic insulator sheet **14** in proper registry with the respective electrode sections **7** to **13** on the phosphor-bearing sheet **2** and with terminal contact members **7***b* to **13***b* temporarily tacked in place to the front plastic encapsulating sheet **22** and provided with inner metal foil lead portions **7***a* to **13***a* extending to and overlying the apertures **15** over the respective electrode sections **7** to **13**. As in the case of the lay-up assembly shown in FIG. 7, the front electrode layer **4** may be provided either on the front vapor-barrier sheet **19** as shown in FIG. 8, or it may be provided on the phosphor-bearing layer **2**. The stacked lay-up assembly **25** is then laminated together in a suitable manner, as in the manner described above in connection with FIG. 7. During this laminating operation, the leads **7***a* to **13***a* from the terminal contact members **7***b* to **13***b* are forced through the apertures **15** in the plastic insulator sheet **14** into firm contact with the respective electrode sections **7** to **13** so as to make good electrical contact therewith.

In the operation of the electroluminescent display device **1** according to the invention, a source of alternating current potential is connected between the contact terminal **20** and any preselected one or more of the contact terminals **7***b* to **13***b*. The A.C. potential thus applied to the appropriate electrode section or sections **7** to **13** of the segmented electrode **5** causes the selected electrode section or sections to excite to luminescence the portions of the electroluminescent phosphor located between the said electrode section(s) and the front electrode **4**. A corresponding luminous pattern, conforming to that of the energized back electrode section(s), is thus produced and emitted by the display panel **1**. By providing a suitable switching arrangement between the A.C. source and each of the contact terminals **7***b* to **13***b*, a selected luminous pattern, which in the case of the particular digital display device **1** illustrated may be in the form of any digit from 0 to 9, can thus be made to appear at the light-emitting or viewing side of the display device. During the operation of the display device **1**, the plastic insulator sheet **14** of low permittivity which, in accordance with the invention, is located between and electrically insulates the leads **7***a* to **13***a* from the segmented electrode layer **5** other than at their points of connection to their respective electrode sections **7** to **13**, effectively prevents the leads **7***a* to **13***a* from capacitively coupling to the light-transmitting front electrode layer **4** and so exciting to luminescence the overlying portions of the electroluminescent phosphor layer **2**, to the detriment of the appearance of the luminous pattern produced by the display device.

By providing, in accordance with the invention, the plastic insulator sheet **14** of low dielectric constant or permittivity as an insulating separator between the electrode leads **7***a* to **13***a* and the various electrode sections **7** to **13** (other than at the points of electrical connection of each lead to its respective electrode section), it is possible for the lead to any individual electrode section to extend therefrom to the edge of the display device in a path extending across, but without the lead electrically contacting any of the other electrode sections. As a result, there is no need for spacing any of the electrode sections **7** to **13** sufficiently far apart from one another to permit passage therebetween of a lead without touching and electrically contacting such electrodes. Consequently, the discrete electrode sections **7** to **13** of the display device **1** according to the invention need only be spaced apart a very slight distance of as little as .001 inch or so, just sufficient to insure their not electrically contacting one another, at the points or regions where they meet. Because of this, the electroluminescent display device construction according to the invention permits maximum utilization of the available surface area thereof for display purposes, with resulting greatly improved definition or delineation of the illuminated display pattern produced by the device such as, for example, the digits 0 to 9 in the case of the particular digital display device **1** described and illustrated herein. Moreover, the use in accordance with the invention of a preformed apertured insulator sheet **14** of low permittivity plastic material for the purpose of electrically insulating and shielding the back electrode current supply leads **7***a* to **13***a* from all the electrically active components of the display device other than the respective electrode sections **7** to **13** to which each particular lead is connected, serves to greatly simplify and facilitate the construction and manufacture of an electroluminescent display device of the edge contact terminated type which is not subject to excitation of, and resulting undesired light emission from those portions of the phosphor layer directly overlying the current supply leads to the segmented back electrode by reason of the applied A.C. potential.

The method disclosed herein is claimed separately in my copending divisional application Serial No. 544,018, filed April 20, 1966.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electroluminescent display panel comprising a layer of electroluminescent phosphor having a light-transmitting front electrode layer on one side thereof and a segmented back electrode layer on the other side thereof comprised of an array of discrete electrode sections, an apertured insulator sheet of low dielectric constant organic thermoplastic material overlying the segmented electrode side of said phosphor layer and having apertures over respective ones of said discrete electrode sections, and a plurality of electrically conductive leads overlying said insulator sheet and said phosphor and front electrode layers and being electrically connected to respective ones of said electrode sections through the said apertures in said insulator sheet, said conductive leads extending to the edge of said insulator sheet and being insulated thereby from capacitively coupling to the said light-transmitting electrode layer upon application of an A.C. potential to the said leads and said light-transmitting electrode layer.

2. An electroluminescent display panel as specified in claim **1** wherein the said leads are comprised of coatings of electrically conductive material on the said plastic insulator sheet and on the portions of said electrode sections underlying the said apertures in the insulator sheet.

3. An electroluminescent display panel as specified in claim **1** wherein the said leads are comprised of metal foil strips adhered to the said plastic insulator sheet and to the portions of said electrode sections underlying the said apertures in the insulator sheet.

4. An electroluminescent display panel as specified in claim **1** having, in addition, a front water-vapor barrier layer of a light-transmitting hydrophilic thermoplastic material overlying the said light-transmitting front electrode layer, a back barrier layer of low water-vapor permeability overlying both the said electrically conductive leads and the said plastic insulator sheet, an outer encapsulating envelope comprised of sheets of thermoplastic material of low water-vapor permeability laminated

to the opposite sides of the display panel and sealed together around their periphery, and an additional electrically conductive lead connected to said light-transmitting front electrode layer, all of said electrically conductive leads extending outwardly through the peripheral seal between the said thermoplastic encapsulating sheets.

5. An electroluminescent display panel as specified in claim 4 wherein the said back barrier layer comprises a layer of hydrophilic thermoplastic material.

6. An electroluminescent display panel as specified in claim 4 wherein the said back barrier layer comprises a sheet of hydrophilic thermoplastic material and an overlying sheet of metal foil.

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