

May 21, 1968

V. VODICKA

3,384,770

ELECTROLUMINESCENT DISPLAY DEVICE HAVING FOLDED ELEMENTS

Filed July 18, 1966

2 Sheets-Sheet 1

Fig. 1.

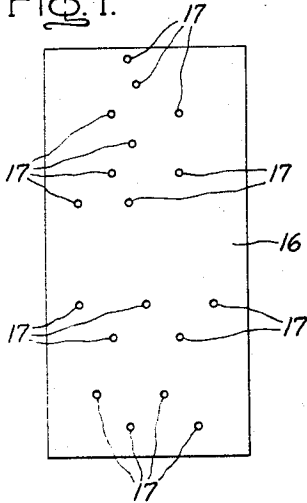


Fig. 2.

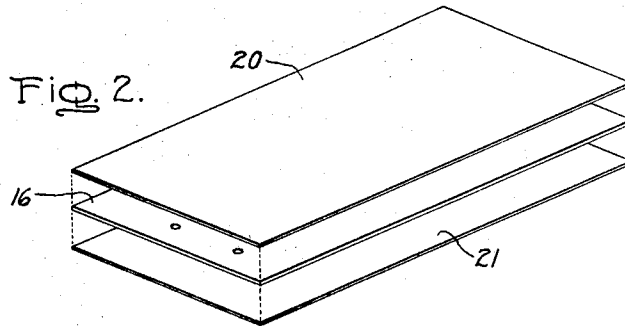


Fig. 3.

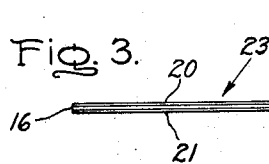


Fig. 4.

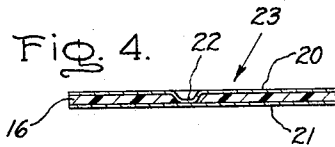


Fig. 5.

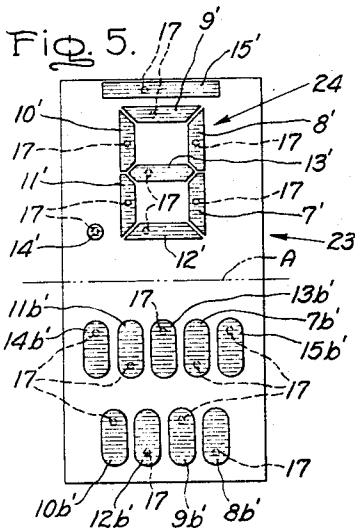


Fig. 6.

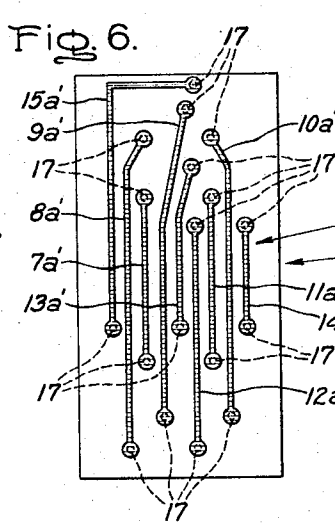


Fig. 7.

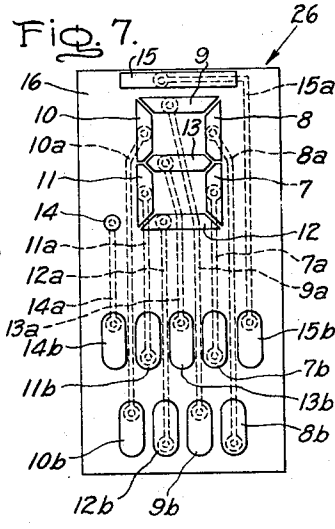


Fig. 9.

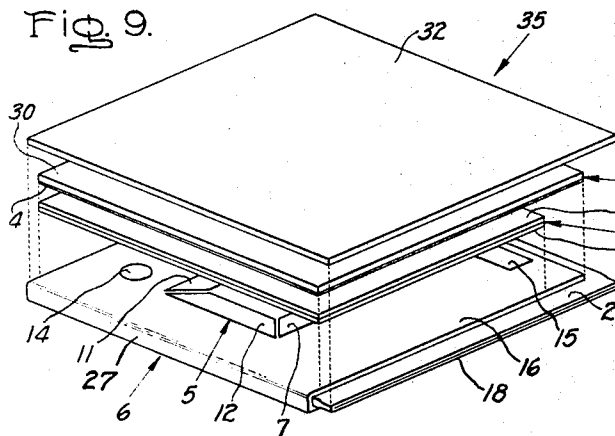
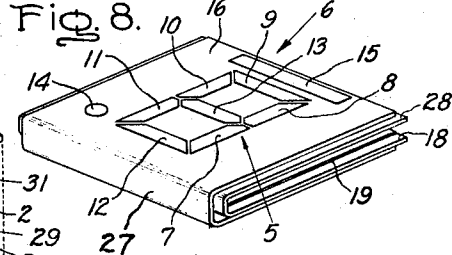


Fig. 8.



Inventor:
Vincent Vodicka
by *James J. Szynal*
His Attorney

May 21, 1968

V. VODICKA

3,384,770

ELECTROLUMINESCENT DISPLAY DEVICE HAVING FOLDED ELEMENTS

Filed July 18, 1966

2 Sheets-Sheet 2

Fig. 10.

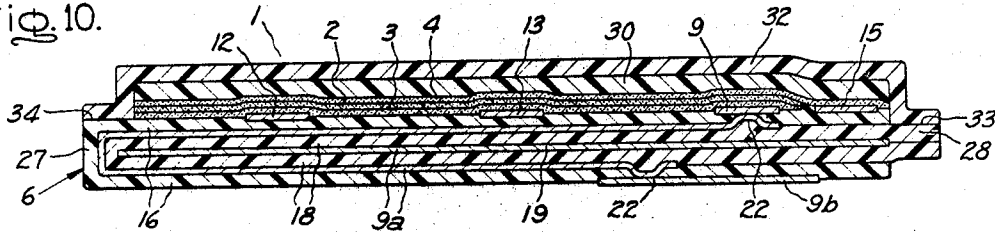


Fig. 11.

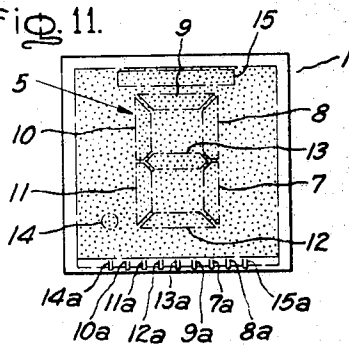


Fig. 12.

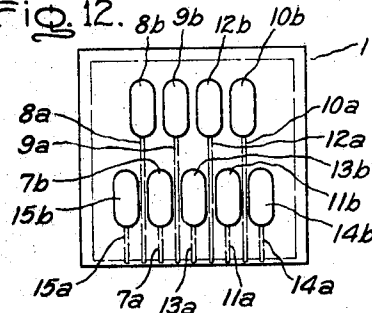
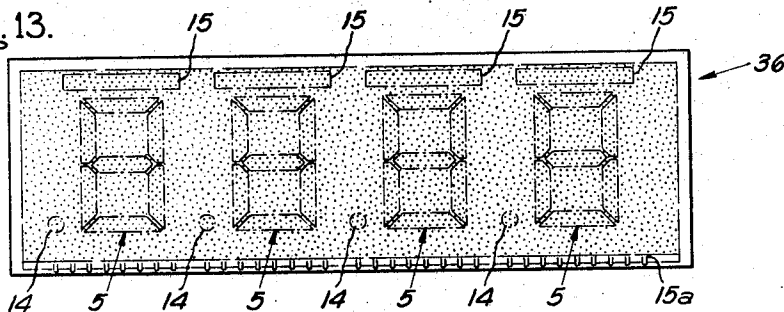


Fig. 13.



Inventor:
Vincent Vodicka
by *James J. Layna*
His Attorney

1

3,384,770

ELECTROLUMINESCENT DISPLAY DEVICE HAVING FOLDED ELEMENTS

Vincent Vodicka, South Euclid, Ohio, assignor to General Electric Company, a corporation of New York
Filed July 18, 1966, Ser. No. 565,833
6 Claims. (Cl. 313-108)

ABSTRACT OF THE DISCLOSURE

An electroluminescent display device has a back electrode and terminal contact subassembly comprised of an organic plastic insulator sheet having a plurality of apertures and folded over upon itself, with one of its flat outer faces provided with a segmented back electrode layer consisting of a plurality of discrete electrode sections and its other flat outer face provided with a plurality of terminal contacts, the inner face of the folded insulator sheet being provided with a plurality of circuit leads, the electrode sections and terminal contacts and circuit leads all consisting of metal foil adhered to the respective faces of the insulator sheet and the circuit leads each being adhered to and electrically connected with a respective one of the electrode sections and with a respective one of the terminal contacts through respective ones of the apertures in the insulator sheet. An electroluminescent phosphor layer overlies the segmented electrode face of the back electrode subassembly, and a light-transmitting front electrode layer overlies the phosphor layer. The insulator sheet may be folded over an insulating organic plastic separator sheet which, in turn, may be folded around a metal foil insert sheet that serves as a water-vapor barrier for the back side of the display device. The front electrode layer may be in surface contact with a metal foil connector lead provided on the electrode carrying face of the folded insulator sheet and adhered to and electrically connected, through a respective aperture in the insulator sheet, with an additional metal foil circuit lead provided on the inner face of the insulator sheet and adhered to and electrically connected with a respective one of the metal foil terminal contacts through a respective aperture in the insulator sheet.

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.

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.

In my copending application Ser. No. 546,114, filed Apr. 4, 1966, I have disclosed and claimed an electroluminescent display device having a segmented display type back electrode, and current supply or circuit leads,

2

formed on the opposite sides of an organic thermoplastic insulator sheet by the selective etching, in the patterns of the segmented electrode and the circuit leads, of metal foil sheets laminated to the opposite sides of the insulator sheet, the metal foil electrode segments being laminated and electrically connected to respective ones of the circuit leads through apertures in the insulator sheet. Such a manner of fabrication enables the manufacture of miniature type electroluminescent display devices, having very small size electrode segments and circuit leads with exceedingly close tolerances or spacing therebetween, while at the same time affording freedom from electrical shorts between the individual electrode segments or circuit leads as well as sharp definition to the individual electrode segments forming the display pattern. Also, the use of metal foil for the electrode segments and circuit leads assures against the formation of fissures or breaks in the individual electrode segments or circuit leads, and resulting disruption in the electrical continuity thereof and consequent inoperativeness of the display device, such as frequently occurs during the subsequent heat lamination and usage of the device in those cases where the electrode segments and circuit leads are made of an electrically conductive printing ink or paint by conventional printed circuit techniques.

In the electroluminescent display device as disclosed in my said copending application, the terminal contacts thereof are located at the marginal edge of the device. For certain applications, however, it is desirable that the terminal contacts be located at the back or underside of the display device and, in some cases, in a different positional relation thereon from that of the back electrode segments themselves. Because of the important advantages inherent in the back electrode construction features of the display device disclosed in my said copending application, the incorporation of such construction features in a so-called back contact terminated type display device is therefore an especially desirable consideration.

It is an object of the invention to provide an electroluminescent display device or panel of the heat-laminated flexible type having its terminal contacts located on the back side or underface of the device and which lends itself to production manufacture by a simplified and easily controlled manufacturing process with a minimum amount of production rejects or inoperative devices.

Another object of the invention is to provide an electroluminescent display device or panel of the heat-laminated flexible type having its terminal contacts located on its back side or underface while at the same time having an extremely effective moisture-tight seal of its current supply conductors into the device.

Briefly stated, and in accordance with one aspect of the invention, the back or pattern-forming electrode component of an electroluminescent display device or panel, and the associated conductor or circuit leads and terminal contacts therefor, are constituted by a composite back electrode and terminal contact subassembly formed by laminating metal foil sheets to the opposite faces of an apertured plastic insulator sheet of a low dielectric constant organic thermoplastic material to cause the metal foil sheets to contact and electrically connect with one another through apertures in the insulator sheet, and then selectively etching away the metal foil sheets in a predetermined pattern to leave the display electrodes and the terminal contacts therefor on one face of the insulator sheet, on opposite sides of a transverse fold line thereof, and to leave the circuit or conductor leads on the other face of the insulator sheet, each circuit lead being in surface engagement with and thus electrically connected to a given one of the back electrode sections and to a given one of the terminal contacts through respective apertures in the insulator sheet. The insulator

3

sheet with the etched metal foil electrode sections, terminal contacts and circuit leads thereon, is folded over upon itself along its transverse fold line, with its display electrodes and terminal contacts facing outwardly, around an insulating separator sheet of an organic thermoplastic material, the folded insulator and separator sheets thus constituting the electrode and terminal contact subassembly of the display device.

In accordance with a further aspect of the invention, the insulating separator sheet may be folded over as a unit with the insulating sheet around a metal foil insert sheet which then serves as an additional water-vapor barrier for the back side of the electroluminescent display device. The folded over back electrode and terminal contact subassembly as described above is then assembled together with an electroluminescent phosphor layer on its segmented electrode face and with an overlying light-transmitting front electrode layer, as by laminating the said layers thereto, to thereby form the completed electroluminescent display device or panel according to the invention. Prior to its assembly with the phosphor and front electrode layers, the back electrode subassembly is preferably prelaminated together, for easy handling purposes.

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 a plan view of the apertured plastic insulator sheet employed in the fabrication of a back electrode subassembly for an electroluminescent display device according to the invention.

FIG. 2 is an exploded perspective view illustrating one of the initial steps in the manufacture of an electroluminescent display device according to the invention wherein metal foil sheets are laminated to the opposite sides of the apertured plastic insulator sheet and over the apertures therein so that they surface contact and electrically connect with one another through the apertures in the insulator sheet.

FIG. 3 is an elevational view along an edge of the metal foil-faced laminate which is formed by the laminating step shown in FIG. 2.

FIG. 4 is a fragmentary sectional view on an enlarged scale of the metal foil-faced laminate shown in FIG. 3, the section being taken through one of the apertures in the insulator sheet of the laminate to show the manner in which the metal foil sheets on the opposite sides of the insulator sheet contact and electrically connect with one another through the apertures therein.

FIGS. 5 and 6 are plan views of opposite faces of the metal foil-faced laminate of FIG. 3 following the application thereto of protective coatings of an acid-resist material in the desired segmented electrode, terminal contact and connector lead pattern on one face (FIG. 5) and in the desired circuit lead pattern on the other face (FIG. 6), with each of the coated areas delineating the electrode sections, terminal contacts and connector lead on one face and each of the coated areas delineating the circuit leads on the other face being in registry with respective ones of the apertures in the plastic insulator sheet of the laminate.

FIG. 7 is a plan view of the electrode and terminal contact side of the laminate of FIG. 3 following the etching away of the unprotected areas of the metal foil sheets on the opposite sides thereof, and the removal therefrom of the patterned acid-resist coatings thereon to expose the underlying metal foil back electrode, terminal contact and connector lead pattern on the one side of the laminate and the circuit lead pattern on the other side thereof.

FIG. 8 is a perspective view of the back electrode and terminal contact subassembly of the display device, formed by the folding over upon itself of the electrode and terminal contact-carrying insulator sheet of FIG. 7, along a transverse fold line thereof, around an insulating plas-

4

tic separator sheet and preferably in addition around a metal foil insert sheet.

FIG. 9 is an exploded perspective view illustrating the stacked assembly of all the component layers or elements of the electroluminescent display device in preparation for the lamination together thereof to form the final completed device.

FIG. 10 is a sectional view on an enlarged scale of the electroluminescent display device according to the invention.

FIG. 11 is a plan view of the light-emitting front or illuminated display side of the electroluminescent display device according to the invention.

FIG. 12 is a plan view of the back or terminal contact side of the display device, and

FIG. 13 is a plan view of the light-emitting front side of a modified form of electroluminescent display device according to the invention for producing a multiple digit display.

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 (FIGS. 10-12) 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 FIG. 10, 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 a suitable organic polymeric matrix material of high dielectric constant material such as is commonly employed for such purpose in so-called organic type electroluminescent cells or lamps, as disclosed for example in U.S. Patent 2,945,976, Fridrich et al., dated July 19, 1960. However, plasticized cyanoethyl polyglucosides such as cyanoethyl cellulose plasticized with cyanoethyl phthalate as described and claimed in U.S. Patent No. 3,238,407, Jaffe, dated Mar. 1, 1966, or cyanoethyl cellulose plasticized with cyanoethyl sucrose as described and claimed in U.S. Patent 3,247,414, Levettan, dated Apr. 19, 1966, are preferred organic matrix materials which form a dense tough film of high dielectric constant and good mechanical and thermal stability. The insulating or voltage barrier layer 3 is comprised of a finely divided insulating material of high dielectric constant such as, for example, barium titanate or titanium dioxide, dispersed in a suitable high dielectric constant organic polymeric matrix material such as that employed for the phosphor layer 2, preferably cyanoethyl cellulose plasticized with cyanoethyl phthalate as referred to above. The light-transmitting electrically conductive front electrode layer 4 may be any type conventionally for such purpose in electroluminescent cells or lamps. Preferably, however, the electrode layer 4 is comprised of a light-transmitting electrically conductive lacquer such as, for example, those described and claimed in copending U.S. applications Ser. No. 556,837, Jaffe et al. filed June 9, 1966 and Ser. No. 333,950, Amans, filed Dec. 27, 1963, both assigned to the assignee of the present invention, and comprising a dispersion of electrically conductive light-transmitting particulate material such as indium oxide in a light-transmitting organic plastic matrix material

such as ethyl hydroxyethyl cellulose or cyanoethyl cellulose plasticized with cyanoethyl phthalate.

As shown in FIG. 8, the segmented back electrode layer 5 is formed in accordance with the invention as a part of a composite back electrode and terminal contact sub-assembly 6 and comprises an array of discrete electrically conductive electrode sections or areas which 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. In the case of the particular digital display or read-out device illustrated, the segmented electrode 5 is composed of seven bar-shaped principal electrode sections or areas 7 to 13 arranged in two side-by-side substantially square or parallelogram-shaped patterns having a common side so as to delineate the block number eight which, as shown, may be located more or less centrally within and aligned with the sides of the square or 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, 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 2,922,933, any digit from 0 to 9 may be made to light up on the display panel. Preferably in addition, the composite back electrode layer 5 is also comprised of a small circularly-shaped electrode section 14 in the form of a dot and located relative to the seven bar-shaped electrode sections 7 to 13 to serve as a decimal point for whatever digit may be displayed thereby. Also in accordance with the invention, the back electrode subassembly 6 is provided with a connector lead section 15 located on the same side thereof as the electrode segments 7 to 13. As shown, the connector lead section 15 may be of bar shape extending across the top of the block figure eight formed by the seven electrode segments 7 to 13. The electrode sections 7 to 14 and the connector lead section 15 are all located on and affixed to one of the exposed outer surfaces of a folded-over plastic insulator sheet 16 (FIG. 8) of low dielectric constant organic thermoplastic material to the other exposed outer surface of which is affixed a plurality of terminal contacts 7b to 15b (FIG. 12) corresponding to and electrically connected to the respective electrode and connector lead sections 7 to 15 by respective circuit leads 7a to 15a affixed to the inner surface of the folded insulator sheet 16. The circuit leads 7a to 15a are in surface contact with, and thus electrically connected to their corresponding electrode and connector lead sections 7 to 15 and to their corresponding terminal contacts 7b to 15b through respective apertures 17 which are formed in the insulator sheet 16 in registry with the electrode and connector lead sections 7 to 15 and with the terminal contacts 7b to 15b. To prevent electrical shorting of the circuit leads 7a to 15a to one another when the insulator sheet 16 is folded over upon itself, an insulating separator sheet 18 of an organic thermoplastic material or other suitable insulating material is inserted between the folded-over portions of the insulator sheet 16. The insulating separator sheet 18 preferably is folded over as a unit with the insulating sheet 16 around a metal foil insert sheet 19 which serves as an additional moisture or vapor barrier for the back side of the display device. The assembly of the folded over insulator sheet 16 with the inserted separator sheet 18, and with the electrode and connector lead sections 7 to 15 on one of its outer surfaces and the terminal contacts 7b to 15b on its other outer surface interconnected by the circuit leads 7a to 15a, and also including the inserted metal foil barrier sheet 19 where employed, forms the back electrode and terminal contact subassembly 6 of the display device.

In accordance with the invention, the composite back electrode subassembly 6 (FIG. 8) is formed by first lami-

nating under heat and pressure, and preferably by a single laminating operation, two sheets 20 and 21 (FIG. 2) of a suitable metal foil, such as aluminum foil or electrolytic etched copper foil having a thickness of, for example, around .8 mil or so, to the opposite sides of a plastic insulator sheet 16 and over a plurality of apertures 17 therein to cause the metal foil sheets to surface engage and electrically connect with one another through the said apertures 17, as shown at 22 in FIG. 4. The apertures 17 are in registry with the respective areas of the insulator sheet 16 onto which are to be applied the individual electrode sections 7 to 14, the connector lead section 15, and the terminal contact sections 7b to 15b. For the purposes of the invention, the plastic insulator sheet 16 is formed of a suitable organic thermoplastic material having a low dielectric constant or permittivity. Examples of organic thermoplastic materials of low permittivity which may be suitably employed for the plastic insulator sheet 16 are polytetrafluoroethylene, polyethylene, and polychlorotrifluoroethylene. In the particular case illustrated, however, the plastic insulator sheet 16 is composed of a polychlorotrifluoroethylene film such as that commercially known as Kel F or Aclar having a thickness of around 2 mils or so. To produce better adherence of the aluminum foil sheets to the polychlorotrifluoroethylene insulator sheet 16, the aluminum foil, prior to its lamination to the insulator sheet, is precoated with an adherence promoting solution such as that commercially known as a 6% Kel F solution. This assures against the etching solution, which in the later stages of the electrode subassembly manufacturing operation is used to etch away portions of the aluminum foil unprotected by an acid-resist coating, from cutting under the protectively coated foil areas and producing an irregular or ragged edge thereon. The lamination of the two metal foil sheets 20, 21 to the opposite sides of the plastic insulator sheet 16 may be carried out between two sheets of aluminum in a suitable hydrostatic laminating press such as, for example, that described and claimed in Fridrich Patent 3,047,052, at a suitable laminating pressure of, for example, around 200 pounds per square inch or so and at a suitable laminating temperature at which the plastic insulator sheet 16 will soften, for example, around 200° C. or so in the case of a polychlorotrifluoroethylene insulator sheet 16.

Following the fabrication of the metal foil-faced laminate 23 (FIGS. 3 and 4) as described above, protective coatings 7' to 15', 7a' to 15a', and 7b' to 15b', of a suitable acid-resist material, such as that commercially known as Universal Resist No. R-511-5A made by the Advance Process Supply Company, are suitably applied, as by a conventional silk-screening operation, in the desired electrode, connector lead, and terminal contact area pattern 24 (FIG. 5) on one face of the laminate 23 and in the desired circuit lead area pattern 25 (FIG. 6) on the other face of the laminate 23. As shown, the acid-resist coating pattern 24 corresponds to the areas of the metal foil 20 which are to form the electrode sections 7 to 14, connector lead section 15 and terminal contact sections 7b to 15b, which sections are in registry with respective ones of the apertures 17 in the insulator sheet 16. Likewise, the acid-resist coating pattern 25 corresponds to the areas of the metal foil 21 which are to form the circuit leads 7a to 15a, each circuit lead area being in registry with a given one of the apertures 17 registered with the electrode and connector lead sections 7 to 15, and also in registry with a given one of the apertures 17 registered with the terminal contacts 7b to 15b. As shown in FIG. 5, the areas forming the electrode sections 7 to 14 and connector lead section 15 are all located to one side of a transverse fold line A of the insulator sheet 16, which fold line may approximately bisect the insulator sheet, while the areas forming the terminal contacts 7b to 15b are all located to the other side of the fold line A. Also as shown in FIG. 5, the seven bar-shaped areas which form the electrode sections 7 to 13 and are arranged to delineate the block figure eight,

are preferably disposed on the insulator sheet 16 so that the block figure eight delineated thereby stands upright relative to the fold line A of the sheet 16.

As further shown in FIG. 5, the areas defining the terminal contacts 7b to 15b are preferably of oblate or pad shape, and are arranged in two rows extending generally parallel to the fold line A of the insulator sheet 16.

After the protective acid-resist coatings 24, 25 have been applied to the opposite faces of the metal foil-faced laminate 23, the unprotected areas of the metal foil facings 20, 21 of the laminate not covered with acid-resist coating material are then chemically removed by suitably contacting the said unprotected metal foil areas with an etching medium or solution for the metal foil which is unreactive with respect to the acid-resist material employed for the protective coatings 24, 25. For this purpose, the protective coated laminate 23 may be simply immersed in a bath of the etching solution so that both sides of the laminate are etched simultaneously. In the case of metal foil sheets 20, 21 made of aluminum, a suitable etching material therefor is a ferric chloride solution such as, for example, that commercially known as "Etchant" manufactured by the Printed Circuit Division of Techniques, Inc., of Englewood, N.J. After the unprotected areas of the metal foil facings 20, 21 of the laminate 23 have been thus etched away, the acid-resist coatings 24 and 25 on the opposite faces of the laminate 23 are then suitably removed therefrom, as by dissolving them off the laminate by application thereto of a solvent for the acid-resist material, to expose the metal foil electrode, terminal contact and circuit lead patterns therebeneath, thereby completing the fabrication of the back electrode and terminal contact carrying prelaminate 26 (FIG. 7). Because of the surface engagement of the metal foil sheets 20, 21 with one another through the respective apertures 17 in the insulator sheet 16 of the laminate 23, each of the electrode and connector lead sections 7 to 15 and terminal contacts 7b to 15b is therefore electrically connected to its corresponding circuit lead 7a to 15a.

Especially in those cases where the segmented electrode sections, terminal contacts and circuit leads of the display device are of minute configuration or are minutely spaced, they may be formed instead by the well known photoetching process, since with such a process the patterned electrode segments, terminal contacts and circuit leads can be formed much more accurately, and to much closer tolerances and spacing, than with a process as described above involving a silk-screening operation for the application of an acid-resist coating in the pattern of the desired electrode and circuit lead configuration on the metal foil sheets 20, 21. In such a photoetching process, the metal foil sheets 20, 21 of the laminate 23 are coated with an acid-resistant photosensitive coating such as that commercially known as Photoresist, made by the Eastman Kodak Company of Rochester, N.Y. The photosensitive coatings on the metal foil sheets 20, 21 of the laminate 23 are then exposed to activating light, such as ultraviolet light, for example, under appropriate masks configured to mask the light from all the areas of the photosensitive coatings other than the electrode and terminal contact, and circuit lead patterns 24 and 25. The photosensitive coatings on the metal foil sheets 20, 21 are then developed, by a conventional photographic developing process, to effect the removal of all the unexposed areas of the photosensitive coatings on the metal foil sheets 20, 21 and leave protective coatings of acid-resist material thereon in the desired electrode and terminal contact, and circuit lead patterns 24, 25 conforming to the patterns of the masks. The unprotected areas of the metal foil sheets 20, 21 are then chemically removed in the same manner as before, i.e., by immersing the laminate 23 in a bath of an etchant for the metal foil, after which the acid-resistant coatings 24 and 25 on the opposite faces of the laminate 23 are then suitably removed therefrom as before, i.e., by dissolving them off the lami-

nate by application thereto of a solvent for the acid-resistant material.

The electrode and terminal contact carrying prelaminate 26 formed as described above and shown in FIG. 7, is then trimmed to proper size and folded over upon itself, with its electrode sections 7 to 41 and terminal contacts 7b to 15b facing outwardly, along the fold line A and around an insulating separator sheet 18 of a suitable organic thermoplastic material such as that employed for the insulator sheet 16. The folded assembly of the prelaminate 26 and separator sheet 18 is then laminated together, under pressure and heat, to thereby form the back electrode and terminal contact subassembly 6 (FIG. 8) of the display device. The insulating separator sheet 18 serves to prevent electrical shorting between the circuit leads 7a to 15a when the prelaminate 26 is folded over upon itself. As shown in FIG. 8, a metal foil insert sheet 19 such as aluminum foil of, for example, 0.8 mil thickness, is preferably also laminated between the folded over portions of the insulator sheet 16 to serve as an additional moisture barrier for the back side of the display device 1. Where such a metal foil insert sheet 19 is employed, it is necessary to insure against the metal foil sheet electrically shorting the circuit leads 7a to 15a. For this purpose, and as shown in FIG. 8, the insulating separator sheet 18 may itself be folded over as a unit with the insulator sheet 16 around the metal foil sheet 19 so as to insulate the latter from the circuit leads 7a to 15a. As also shown in FIG. 8, the insulating separator sheet 18 is preferably made of such size as to extend outwardly beyond the marginal edges of the folded over insulator sheet 16, on the three sides thereof other than its folded edge 27, to form a sealing edge 28 for sealing to a plastic top encapsulating sheet for the display device 1.

The laminated back electrode and terminal contact subassembly 6 formed as described above is then provided, on the face thereof carrying the segmented back electrode layer 5, with the previously mentioned insulating layer 3, phosphor-bearing layer 2, and light-transmitting front electrode layer 4 to form an electrically active assembly which, by itself, may be utilized as an electroluminescent display device. The insulating layer 3, phosphor layer 2, and front electrode layer 4 may be applied to the back electrode subassembly 6 in any suitable manner. Thus, where the front electrode layer 4 is comprised of an electrically conductive lacquer as referred to hereinabove, the three layers 3, 2 and 4 may be successively coated in the form of suspensions directly onto the back electrode subassembly 6 as by means of a conventional doctor blade coating device, with each layer being dried before application of the next layer thereto. Preferably, however, the phosphor layer 2 and insulating layer 3 are preliminarily coated in the form of suspensions onto a temporary support or release sheet of a thin, flexible film material such as polyethylene terephthalate or polytetrafluoroethylene, which are commonly known as Mylar and Teflon, respectively, from which they are then removed or peeled off as an integrated multilayer film 29 (FIG. 9). Also, and particularly in the case where the front electrode layer 4 is comprised of an electrically conductive light-transmitting lacquer as referred to hereinabove, the front electrode layer 4, instead of being formed as a coating on the phosphor layer 2, is preferably coated on a thin, flexible sheet 30 of a suitable transparent organic thermoplastic material, preferably one having hydrophilic properties, i.e., having an affinity for water. Examples of suitable plastic sheet materials having such hydrophilic properties are nylon 6, 6, and nylon 6 such as those commercially known as Caplene and Capran. The composite coated sheet 31 thus formed may then be laminated under pressure and heat together with either a composite back electrode subassembly 6 coated with the insulating and phosphor layers 3 and 2, or together with a composite back electrode subassembly 6 and a

separate multi-layer film 29 composed of the insulating and phosphor layers 3 and 2, to form the electrically active electroluminescent display device assembly.

Because the light output of an electroluminescent cell or lamp deteriorates rapidly on exposure to water vapor, such as the moisture normally present in the atmosphere, it is preferable to encapsulate the electrically active elements of the electroluminescent display device 1 according to the invention in a substantially vapor-tight enclosure as well as to also incorporate suitable water-vapor barrier layers therein. Accordingly, as shown in FIGS. 9 and 10, the electrically active elements 2, 3, 4, and 5 of the electroluminescent display device 1 according to the invention are preferably laminated between the thermoplastic insulating and separator sheets 16, 18 of the back electrode and terminal contact subassembly 6 on the one hand, and a top outer encapsulating sheet 32 on the other hand formed of a light-transmitting thermoplastic material of low water vapor permeability. The encapsulating sheet 32 overreaches the margins of the elements 2, 3, 4 and 5 and is sealed around its edges to the protruding sealing edge 28 of the plastic separator sheet 18 (as shown at 33 in FIG. 10) and to the folded marginal edge 27 of the plastic insulator sheet 16 (as shown at 34 in FIG. 10) to thereby effect the encapsulation of the elements 2, 3, 4 and 5 of the display device 1. The top outer encapsulating sheet 32 is 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, such as that commercially known as Kel F or Aclar, preferably around 5 mil thickness.

To produce such an encapsulated electroluminescent display device 1 according to the invention, the composite back electrode subassembly 6 is simply stacked together with the other component elements of the electroluminescent display device as in the manner shown in FIG. 9 for example, to form a lay-up assembly 35 which is then laminated together under heat and pressure, preferably in an evacuated chamber, to form the completed electroluminescent display device 1 according to the invention. In making the lay-up assembly 35 in readiness for the lamination together thereof, the back electrode and terminal contact subassembly 6 is placed in the laminating press with its segmented electrode side 5 facing upwardly. The preformed multilayered film 29 comprised of the phosphor layer 2 and the insulating layer 3 is placed in proper position on top the segmented electrode-carrying side of the composite back electrode subassembly 6 so as to completely overlie all the electrode segments 7 to 14 but leave exposed the connector lead section 15. To this end, the multilayered film 29 comprised of the phosphor layer 2 and insulating layer 3 may be made of shorter dimension than the electrode-carrying face the back electrode subassembly 6 in the direction extending from the folded edge 27 thereof so as not to overlie the connector lead section 15, when the film 29 is in place in the lay-up assembly 35. The multilayer sheet 31, comprised of a thermoplastic water-vapor barrier sheet 30 faced with a front light-transmitting electrode layer 4 comprised of a coating of a light-transmitting electrically conductive lacquer as described hereinabove, is then placed over the composite phosphor-insulator layer film 29, with its conductive electrode side 4 next to the phosphor layer 2, following which the top thermoplastic encapsulating sheet 32 is then placed in proper position on top the stacked assembly.

The laminating of the lay-up assembly 35 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 35 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. The stacked lay-up assembly 35 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 air or other fluid is admitted into the closed chamber of the press over the diaphragm therein to exert hydrostatic pressure on the stacked lay-up assembly 35, vacuum is applied under the diaphragm to remove any trapped gases or moisture from the space therebelow and from the lay-up assembly 35 in the said space, and heat is then applied by suitable means to the stacked assembly, as by passing an electric current through the metal foil diaphragm, in order to cause the plastic insulator and separator sheets 16 and 18, and the plastic top encapsulating sheet 32, to soften and seal together at their margins so as to encapsulate the electrically active elements 2, 3, 4 and 5 of the electroluminescent display device and complete the fabrication thereof. During the laminating process, the front electrode layer 4 is pressed into intimate contact with the connector lead section 15 left uncovered by the multilayer film 29 of the phosphor and insulating layers 2 and 3, thus making good electrical contact therewith. By virtue of its said electrical connection with the connector lead section 15, the front electrode layer 4 is thereby electrically connected, through the circuit lead 15a for the connector lead section 15, to the corresponding terminal contact 15b.

In the operation of the electroluminescent display device 1 according to the invention, a source of alternating current potential is connected between the terminal contact 15b and any preselected one or more of the terminal contacts 7b to 14b. The A.C. potential thus applied to the appropriate electrode section or sections 7 to 14 of the segmented electrode 5 causes the selected electrode section or sections to excite to luminesce the portions of the electroluminescent phosphor layer 2 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 device 1. By providing a suitable switching arrangement between the A.C. source and each of the terminal contacts 7b to 14b, 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 or .1 to .9, can thus be made to appear at the light-emitting or viewing side of the display device. For example, where it is desired to display the digit "1" as a lighted configuration, an electrical potential is applied across the front electrode 4 and the sections 7, 8 (or 10, 11) of the back electrode 5. During the operation of the display device, the plastic insulator sheet 16 of low permittivity which, in accordance with the invention, is provided between the circuit leads 7a to 14a and the segmented electrode layer 5 to electrically insulate them from one another other than at their respective points of connection, prevents the circuit leads 7a to 14a from effectively capacitatively coupling to the light-transmitting front electrode layer 4 and so exciting to luminesce the overlying portions of the electroluminescent phosphor layer 2, to the detriment of the appearance of the luminous pattern desired to be produced by the display device.

While the invention is illustrated in FIGS. 1 to 12 as embodied in an electroluminescent display device for displaying a single digit or letter or other character, it may be embodied as well in a display device 36 for displaying a plurality of digits or letters or other characters, as illustrated in FIG. 13. The multi-digit display device 36 there shown is provided with a plurality (four in the particular case illustrated) of the block figure eight segmented back electrodes 5, decimal point electrodes 14 and connector lead sections 15, all of which are located on a single insulator sheet 16. The individual electrode sections 7 to 14 of each of the four segmented back electrodes 5 are each connected by separate circuit leads 7a to 14a to separate terminal contacts 7b to 14b which also are located on the single insulator sheet 16. The connector lead sections 15, however, are preferably all connected to a single circuit lead 15a and terminal contact 15b. By selectively applying a source of A.C. potential across the terminal contact 15b for the front electrode 4 and preselected ones of the terminal contacts 7b to 14b for one or more of the four segmented back electrodes 5, by means of a suitable switching arrangement, a selected luminous digital display in the form of any number from .0001 to 9999, to four significant numbers, may be made to appear on the front face of the display device 36.

Because of the comparatively high tensile strength of the metal foil of which the electrode sections 7 to 14, the connector lead section 15, and the circuit leads 7a to 15a and terminal contacts 7b to 15b are constituted, as compared to that of the silver or other type electrically conductive silk-screen inks or paints such as have been proposed for such electrode sections and circuit leads in display devices of the heat-laminated type, the metal foil electrode sections, circuit leads and terminal contacts are therefore able to withstand, without breaking or fissuring, the tensile stresses to which they are normally subjected during the heat lamination of the display device because of the considerable difference in the heat expansion coefficients, and therefore in the degree of expansion, between the metal foil electrode sections and circuit leads on the one hand and the plastic insulator sheet on which they are laminated on the other hand. As a result, electroluminescent display devices constructed according to the invention do not suffer from disruption of the electrical continuity of their electrode sections and circuit leads, during the heat lamination of the device, such as would otherwise render the device inoperable. The production manufacture, therefore, of such flexible heat-laminated type electroluminescent display devices can be accomplished with substantially complete freedom from production rejects due to such electrical discontinuity faults. In addition, the laminating of the two metal foil sheets 20, 21 together through the apertures 17 in the insulator sheet 16 assures the positive electrical connection of all the electrode and connector lead sections 7 to 15 and all the terminal contacts 7b to 15b to their respective circuit leads 7a to 15a at all times. Thus, display devices according to the invention will not become inoperative because of any interruptions in such electrical connections.

By forming the back electrode subassembly 6 in the manner according to the invention, wherein the terminal contacts 7b to 15b are affixed to the same surface of the plastic insulator sheet 16 as the back electrode and connector lead sections 7 to 15 and are removed a considerable distance therefrom (as is evident from FIG. 5), and the insulator sheet 16 then folded around the plastic separator sheet 18 so that the electrode and connector lead sections 7 to 15 are located on one of the outwardly facing sides of the folded insulator sheet 16 and the terminal contacts 7b to 15b are located on the other of its outwardly facing sides, an electroluminescent display device of the back contact terminated type is thereby produced in which the lead-in conductors or circuit leads 7a to 15a have an exceptionally long-path seal into the device so

that an effective seal of the lead-in conductors is obtained against the penetration of water vapor into the device such as normally causes depreciation in the light output of the device. Moreover, this long-path seal of the lead-in conductors or circuit leads 7a to 15a into the display device 1 is obtained without adding any appreciable thickness thereto. The folded construction of the back electrode subassembly 6 also permits the incorporation, into the back or underside of a display device of the back contact terminated type, of a metal foil overlay 19 to serve as a barrier against the penetration of water vapor into the display device 1 directly through the back wall thereof.

The protection against water vapor penetration thus afforded by the long-patch seals of the lead-in conductors or circuit leads 7a to 15a into the display device 1, coupled with that afforded by the metal foil vapor barrier 19, therefore serves to effectively prevent the penetration of water vapor into the display device through its back or underside. Since the penetration of water vapor into the display device 1 through its top or light-emitting front side is effectively prevented by the presence thereon of the relatively moisture-impervious plastic encapsulating layer 32, the display device 1 according to the invention therefore is substantially free from water-vapor penetration and thus has good light maintenance.

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

1. An electroluminescent display device comprising a back electrode and terminal contact assembly comprised of an apertured insulator sheet of low dielectric constant organic thermoplastic material having a plurality of apertures therein and folded over upon itself, said folded insulator sheet being provided on one of its flat outer surfaces with a back electrode section and a connector lead section and on its other flat outer surface with a plurality of terminal contacts, said folded insulator sheet being provided on its inner surface with a plurality of individual circuit leads, said electrode and connector lead sections and said terminal contacts and circuit leads all consisting of metal foil adhered to the respective surfaces of the insulator sheet, the said circuit leads each being adhered to and electrically connected with a respective one of said terminal contacts and with a respective one of said electrode and connector lead sections through respective ones of the said apertures in the insulator sheet, an electroluminescent phosphor overlying the said one outer surface of the said insulator sheet and the said back electrode thereon, and a light-transmitting front electrode layer overlying said phosphor layer and electrically connected to the said connector lead section.

2. An electroluminescent display device comprising a back electrode and terminal contact assembly comprised of an apertured insulator sheet of low dielectric constant organic thermoplastic material having a plurality of apertures therein and folded over upon itself, said folded insulator sheet being provided on one of its flat outer surfaces with a segmented back electrode layer consisting of a plurality of discrete electrode sections and on its other flat outer surface with a plurality of discrete terminal contacts, said folded insulator sheet being provided on its inner surface with a plurality of individual circuit leads, said electrode sections and terminal contacts and said circuit leads all consisting of metal foil adhered to the respective surfaces of the insulator sheet, the said circuit leads each being adhered to and electrically connected with a respective one of said electrode sections and with a respective one of said terminal contacts through respective ones of the said apertures in the insulator sheet, an electroluminescent phosphor layer overlying the said insulator sheet and the segmented back electrode thereon, and a light-transmitting front electrode layer overlying said phosphor layer, said circuit leads being shielded by said insulator sheet against effectively coupling capacitatively to the said front electrode upon

13

application of an A.C. potential to the said circuit leads and front electrode.

3. An electroluminescent display device as specified in claim 2 having, in addition, an insulating separator sheet of an organic thermoplastic material inserted between the folded over portions of the said apertured insulator sheet. 5

4. An electroluminescent display device as specified in claim 2 having, in addition, an insulating separator sheet of an organic thermoplastic material folded over upon itself and inserted between the folded over portions of the said apertured insulator sheet, and an insert layer of metal foil inserted between the folded over portions of the said folded thermoplastic separator sheet. 10

5. An electroluminescent display device as specified in claim 2 wherein the said folded insulator sheet is further provided on its said one outer surface with a metal foil connector lead section adhered thereto and electrically connected to the said front electrode layer, the said in- 15

14

ulator sheet having at least one of its said apertures in registry with said connector lead section and being also provided on its inner surface with an additional one of said circuit leads adhered to and electrically connected with both said connector lead section and a respective one of said terminal contacts through the respective apertures registered therewith.

6. An electroluminescent display device as specified in claim 5 wherein the said connector lead section and front electrode have portions located beyond the marginal edge of the phosphor layer and in surface interengagement to thereby provide the said electrical connection between the connector lead section and the front electrode.

No references cited.

ROBERT SEGAL, *Primary Examiner.*