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MANUFACTURE OF ELECTROLUMINESCENT CELLS

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Fig. 1.

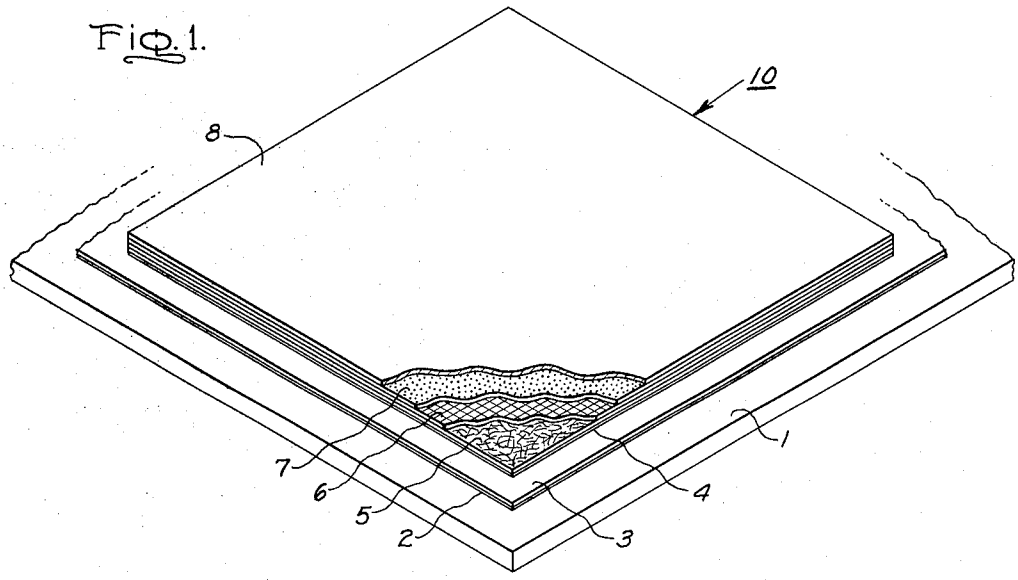
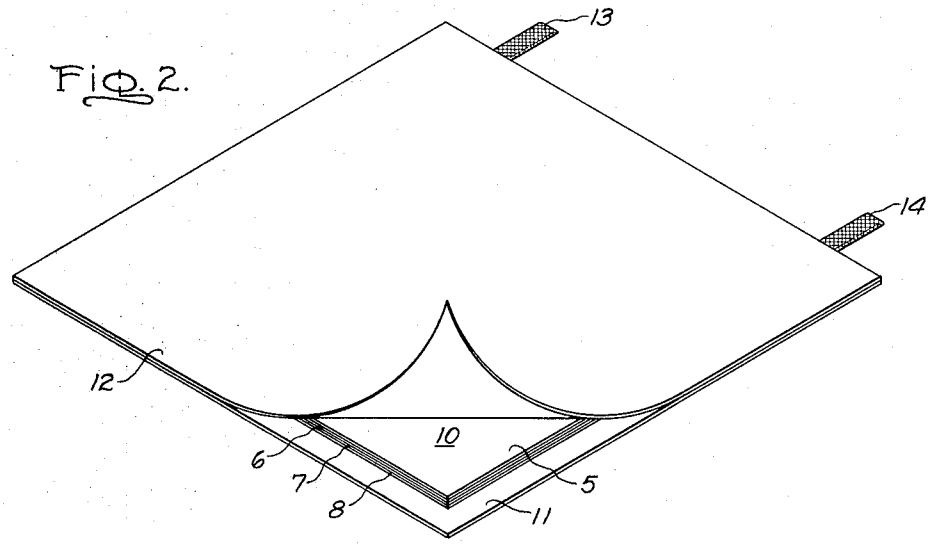


Fig. 2.



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MANUFACTURE OF ELECTROLUMINESCENT CELLS

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This invention relates in general to electroluminescent lamps or cells and, more particularly, to a new and improved method for making flexible type electroluminescent cells.

As presently known in the art, an electroluminescent lamp or cell generally comprises a layer of phosphor capable of generating light under the action of an electric field and sandwiched between a pair of conductive layers, at least one of the conductive layers being transparent or capable of transmitting light. One form of electroluminescent lamp now well known is of flexible character, as described in U.S. Patent 2,945,976, Fridrich et al., assigned to the assignee of this invention. Such an electroluminescent lamp comprises a flexible laminated assembly of electrically active layers or elements encased in a thin envelope of thermoplastic sheet material which has been evacuated and sealed, by pressure and heat, around its edges.

The electrically active elements contained in such a flexible lamp heretofore have generally comprised a back electrode such as aluminum foil coated with an insulating layer of high dielectric constant material which in turn is overcoated with a layer of electroluminescent phosphor, and a transparent conducting sheet placed over the coated side of the aluminum foil. The coated aluminum foil and transparent conducting sheet are usually stacked between transparent thermoplastic sheets to form an electroluminescent lamp lay-up or assembly, the thermoplastic sheets overreaching the foil and conducting sheet at their marginal edges. The stacked assembly of electroluminescent lamp elements is then laminated under heat and pressure to form the completed lamp.

In an electroluminescent lamp or cell such as described above and in the Fridrich et al. patent, the aluminum foil and the transparent conductive sheet constitute the electrodes of the lamp. The application of an alternating potential across the aluminum foil and the conductive sheet results in the creation of an electric field across the phosphor layer which causes the phosphor to emit visible light. The visible light thus emitted by the phosphor layer may readily pass through the transparent conductive sheet.

The transparent conductive sheet employed in the production of an electroluminescent lamp or cell such as that described above is generally comprised of electrically conductive glass paper, the glass fibers of which are coated with a thin light-transmitting film of electrically conductive material such as, for example, a metal or a metallic oxide, or an indium compound as described more fully in U.S. Patent No. 2,849,339, Jaffe, assigned to the assignee of this invention. Extreme care must be taken when handling or cutting such thin glass paper since it is quite delicate and subject to mechanical damage. For this reason, it has been the practice heretofore, in the manufacture of electroluminescent cells or lamps of the above described character, to coat the insulating and phosphor layers onto the back electrode of the cell rather than onto the glass paper since any attempt to coat the insulating and phosphor layers directly onto the conductive glass paper by ordinary coating methods would be likely to result in the rupture and destruction of the glass paper. The coating of the insulating and phosphor layers onto the back electrode of the electroluminescent cell makes it

necessary to employ as the back electrode a continuous or imperforate member, such as aluminum foil, onto which the insulating and phosphor layers may be coated. Such prior cell-making procedures therefore do not lend themselves to the manufacture of flexible electroluminescent cells with back electrodes of perforate character in the form of various patterns, designs or indicia such as may be desirable in some applications.

As pointed out previously, in the prior manufacturing procedures the coated aluminum foil and the conductive glass paper are generally stacked between transparent thermoplastic sheets and the entire assembly than laminated together under heat and pressure. The laminating operation not only is intended to seal together the overlapping marginal edges of the thermoplastic sheets so as to form an encapsulating envelope for the electrically active portion of the electroluminescent cell, but also is intended to result in a tight bond between the conductive glass paper and the phosphor layer on the aluminum foil. When a tight bond between the phosphor and the conductive glass paper results, the electroluminescent lamp or cell lights evenly with relatively high light intensity. However, it has been found that with such prior lamp manufacturing procedures, the desirable bond between the conductive glass paper and the phosphor layer is not always accomplished by the laminating operation. When the bond is not accomplished, the glass paper may separate from the phosphor layer, and as a result, the lamp or cell will light unevenly and the light emitted will be of relatively low intensity.

It is an object of this invention to provide a new and improved method for making an electroluminescent cell or lamp.

Another object of this invention is to provide a new and improved method for making an electroluminescent lamp which substantially eliminates the possibility of the transparent conductive sheet and the phosphor layer of the lamp subsequently becoming separated or delaminated such as to adversely affect the light performance of the lamp.

Still another object of this invention is to provide an economical and rapid method of fabricating electroluminescent cells which lends itself to the fabrication of such cells by a continuous process.

A further object of this invention is to provide a method of making an electroluminescent cell having one of its electrodes of electrically conductive glass paper and its other electrode of perforate character.

Briefly stated, in accordance with the invention, these and other objects are attained by temporarily supporting or adhering electrically conductive glass paper on a suitable substrate or backing such as a flexible plastic film, then applying to the supported glass paper the various other electrically active layers of an electroluminescent cell (i.e., the phosphor and insulating layers and the other conductor layer) in the proper succession they normally occupy in the cell, and finally separating the temporary support or substrate from the glass paper overlaid with the said electrically active layers. The resultant unitary electrically active electroluminescent cell assembly may then be placed between thermoplastic sheets or laminae and the stacked structure thus formed then laminated together under heat and pressure.

Further objects and advantages of our invention will be apparent from the following detailed description of species thereof taken in connection with the accompanying drawings in which:

FIG. 1 is a pictorial view of the electrically active portion of an electroluminescent cell made in accordance with the invention, portions of the different layers being removed to show the underlying layers; and

FIG. 2 is a pictorial view of a complete flexible laminated electroluminescent cell made in accordance with the invention, one corner of the thermoplastic envelope thereof being peeled back to show the internal electrically active portion of the cell.

Referring first to FIG. 1, the manufacture of an electroluminescent lamp or cell in accordance with a representative embodiment of our invention may be accomplished by first coating a temporary support plate **1** composed of glass or a similar rigid material with a small quantity of a suitable viscous liquid such as, for instance, Arochlor or a similar oil having adhesion promoting qualities, the oil forming a thin layer **2**. A thin temporary support sheet or film **3** of suitable flexible material, for instance, plastic material such as polyethylene terephthalate (Mylar) or polytetrafluoroethylene (Teflon), is placed on the liquid layer **2** and is rolled flat, the liquid layer causing the temporary support sheet or film **3** to be detachably adhered to the surface of the temporary support plate **1**. Instead of employing a liquid adhering medium **2** for such purpose, the detachable attachment of the temporary support sheet or film **3** to the support plate **1** may be effected in any other suitable manner, as by the use of vacuum, for instance.

The flexible support sheet **3** is next coated with a solution of a suitable dielectric material, preferably an organic polymeric material such as, for example, a solution of cyanoethyl cellulose and cyanoethylphthalate, to form a thin layer **4**. A sheet of electrically conductive glass paper **5**, such as that described in the aforementioned Jaffe Patent 2,849,339, is placed flatwise in the wet layer **4** of organic polymeric material so as to absorb the solution. The entire assembly is then gently dried, preferably under a bank of heat lamps. When dry, the conductive glass paper **5** is detachably adhered to the temporary support sheet or film **3** by the solid dielectric material **4** which fills the voids or pores in the glass paper **5** and rigidifies it. It will thus be seen that the temporary support plate **1** and the adhered sheet or film **3**, together with the dielectric material **4**, provide a firm support for the normally fragile glass paper **5**. Since the glass paper **5** is firmly supported by the temporary support means **3** and **4**, its susceptibility to mechanical damage is, therefore, substantially reduced. For this reason, the coating process of the present invention is possible wherein the electroluminescent phosphor layer is deposited directly on the glass paper.

In accordance with the invention, the conducting glass paper **5**, while supported on the temporary support means **1**, **2**, **3** and **4** in the manner described above, is coated first with an electroluminescent layer **6** which may consist of an electroluminescent phosphor such as, for example, zinc sulfide-zinch oxide with suitable activators such as copper, manganese, lead or silver, dispersed in an organic polymeric matrix, and the electroluminescent layer **6** then overcoated with a thin insulating layer **7**, preferably one having a high dielectric constant such as barium titanate, likewise dispersed in an organic polymeric matrix. Examples of suitable polymeric matrices are cellulose nitrate, polyacrylates, methacrylates, polyvinylchloride, 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 cyanoethyl phthalate, as described and claimed in copending application Serial No. 701,907, Jaffe, filed December 10, 1957 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. The phosphor dispersed in the suspending medium such as the above mentioned cyanoethyl cellulose solution, may be applied to the firmly supported glass paper **5** in any suitable manner, for instance, as by spraying or through the use of a doctor blade, to form the phosphor layer **6**. The assembly is then dried as by means of a bank of heat lamps. Thereafter, the high-dielectric constant insulating layer **7** is applied over the phosphor layer **6** in any suitable manner, as by spraying or through the use of a doctor blade, after which the entire assembly is again similarly dried.

Following the drying of the insulating layer **7**, a second or back electrode **8** is applied over the said insulating layer. This electrode **8** may be comprised of some form of electrically conductive paint or paste, or a similar conductive material which may be brushed, sprayed, rolled or silk screened onto the insulating layer **7** either in the form of a continuous imperforate layer thereon or in the form of various patterns, designs or indicia. Alternatively, a layer of evaporated metal such as aluminum may be applied over the insulating layer **7** or, in order to provide an effective moisture barrier for the lamp, metal foil such as aluminum foil may be either laminated to the insulating layer **7** or cemented thereto by conductive cement. Where the electroluminescent lamp or cell is to transmit light from both its sides, the back electrode **8** may be constituted of light-transmitting conductive glass paper such as that employed for the electrode layer **5**, the glass paper being laminated to the insulating layer **7**. In such case, however, either the insulating layer **7** should be of light-transmitting character, or a second layer of electroluminescent phosphor should be placed between the insulating layer **7** and the transparent back electrode **8** so that light may be transmitted therethrough without obstruction. As an alternative, two electroluminescent cells may be constructed back-to-back, sharing a common electrode and having their outer electrodes constituted of light-transmitting conductive glass paper.

Following the application of the second or back electrode **8** over the insulating layer **7**, the entire assembly may be dried again if the nature of the back electrode **8** makes this necessary, and the flexible assembly of the backing sheet **3** together with the applied layers **5**, **6**, **7** and **8** of glass paper, phosphor, insulating material and conductive material, respectively, then removed or peeled from the temporary supporting plate **1**. The other temporary support, i.e., the flexible backing sheet **3**, is then peeled or stripped from the remainder of the assembly, leaving the electrically active portion **10** of the electroluminescent cell comprised of the conductive glass paper **5** and the second or back electrode **8** which form the two electrodes of the cell, together with the discrete layers of phosphor **6** and insulation **7** sandwiched between the electrodes **5** and **8**.

Referring now to FIG. 2, after its separation or removal from the temporary backing support **1**, the electrically active portion **10** of the electroluminescent cell or lamp is then preferably enclosed in a substantially moisture-impervious envelope. For example, the cell portion **10** may be placed between two sheets **11**, **12** of a suitable transparent material, for instance, a thermoplastic material such as polychlorotrifluoroethylene film (Kel-F), the sheets **11** and **12** overreaching the electrically active cell portion **10** at its marginal edges. Projecting flat braids or ribbons **13** and **14** of copper or a similar electrically conductive material are positioned between the sheets **11** and **12** and the electrically active portion **10**, one of the ribbons contacting the conductive glass paper **5** of the cell and the other contacting the back or second electrode **8**. The electrically active cell portion **10** and the sheets **11** and **12** are then suitably laminated together, as in the manner disclosed in U.S. Patent 2,945,976, Fridrich et al., by placing the stacked assembly in a hydrostatic press, between the pressure platens thereof which are separated by a conformable diaphragm suitably of aluminum foil. Compressed fluid or air is admitted into the press chamber, over the diaphragm therein, to exert hydrostatic pressure on the stacked components, vacuum is ap-

plied under the diaphragm to remove any trapped gases or moisture, and heat is supplied by suitable means to the stacked assembly in order to cause the encapsulating sheets **11, 12** to seal together at their margins so as to encapsulate the electrically active cell portion **10**. During the laminating process, the conductors **13** and **14** become embedded in the sheets **11, 12** and are at the same time pressed into intimate contact with the conductive glass paper and the back electrode. Another method of providing a moisture-resistant envelope for the cell assembly involves the use, for the layers **11** and **12**, of epoxy resin impregnated micamat sheets, as disclosed and claimed in copending U.S. application Serial No. 118,112, R. V. Levetan, filed June 19, 1961 and assigned to the same assignee as the present invention.

The new and improved method of the present invention makes possible the coating of layers of phosphor and barium titanate directly onto conductive glass paper without any substantial attendant danger of damage to the glass paper since the glass paper is firmly, yet temporarily, supported in an inflexible position during the coating process. Because the various electrically active layers of the electroluminescent cell are coated directly onto the conductive glass paper electrode of the cell, the method of our invention therefore lends itself to the continuous fabrication of flexible electroluminescent cells from continuous webs of a flexible supporting film **3** and conductive glass paper **5** supplied from rolls thereof and continuously advanced, while adhered to one another, through successive coating application means which operate to deposit on the glass paper the successive coating layers of electroluminescent phosphor, insulating material and the metallic conductor or back electrode layer. In addition, the coating of the phosphor and insulating layers **6** and **7** directly onto the conductive glass paper **5**, instead of onto the back electrode as before, facilitates the production of flexible electroluminescent cells or lamps with back electrodes of perforate character, i.e., in the form of various patterns, designs or indicia.

In contrast to the prior art methods of manufacturing flexible electroluminescent cells which have often resulted in incomplete bonding of the transparent electrically conductive sheet to the layer of electroluminescent phosphor during the laminating operation, the method of the present invention avoids this difficulty by depositing the layer of electroluminescent phosphor directly on the transparent electrically conductive sheet during the coating process to form a unitary electroluminescent assembly, thus assuring a firm bond between the phosphor layer and the transparent conductor without being dependent on a subsequent laminating step to produce the desired bond therebetween. By thus coating the phosphor and barium titanate layers directly onto the conductive glass paper, and so providing a firm bond therebetween, problems of uneven and low intensity lighting in the finished electroluminescent cell are substantially reduced because of the virtual elimination of any tendency of the glass paper and the phosphor layer to separate. Also, it will be seen that the method of the present invention results in a bonding of the phosphor layer to the transparent conductive glass paper during the coating process to form a unitary electroluminescent assembly, rather than delaying the bonding until the laminating operation as in the case of the prior art methods.

While in the specific method described hereinabove for fabricating the electrically active cell portion **10** a rigid support member or plate **1** is detachably or temporarily adhered to the flexible support sheet **3** to provide a firm backing support therefor, it will be understood that the use of such a detachably adhered rigid support member **1** is not essential in all cases but instead may be dispensed with in certain modified forms of our process as, for example, in the case of the continuous process modification described above wherein the continuously advancing flexible support sheet or film **3** may be supported simply by tension alone or by passing it over backing rolls or other suitable backing members, at the regions where the various coatings or layers **4, 5, 6, 7** and **8** are applied to the flexible support sheet or film **3**.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A method of making an electroluminescent cell assembly which comprises detachably adhering electrically conductive glass paper to a temporary backing support sheet by a bonding layer comprising an organic polymeric material filling the voids in and rigidifying the said glass paper, coating said glass paper with a layer of electroluminescent phosphor, applying an electrically conductive layer over said layer of electroluminescent phosphor, and then removing the said temporary support means from the said glass paper.

2. A method of making an electroluminescent cell assembly which comprises detachably adhering electrically conductive glass paper to a temporary backing support sheet by a bonding layer comprising an organic polymeric material filling the voids in and rigidifying the said glass paper, coating said glass paper with a layer of electroluminescent phosphor, overcoating said layer of electroluminescent phosphor with an insulating layer of high-dielectric constant material, applying an electrically conductive layer over said insulating layer, and then removing the said temporary support means from the said glass paper.

3. A method of making an electroluminescent cell assembly which comprises coating flexible sheet material with a thin layer of a solution of an organic polymeric material, laying conductive glass paper flatwise in the said coating and then drying the coating to form a bonding layer filling the voids in and rigidifying the glass paper and detachably adhering it to the flexible sheet material, coating the said glass paper with a layer of electroluminescent phosphor, applying an electrically conductive layer over said phosphor layer, and then stripping the said flexible sheet material off the said glass paper.

4. A method of making an electroluminescent cell assembly which comprises detachably adhering flexible sheet material flatwise to electrically conductive glass paper by a bonding layer comprising an organic polymeric material filling the voids in and rigidifying the said glass paper, coating said glass paper with a layer of electroluminescent phosphor dispersed in a dielectric plastic matrix, overcoating said layer of electroluminescent phosphor with an insulating layer of high-dielectric constant material dispersed in a dielectric plastic matrix, applying an electrically conductive layer over said insulating layer, and then stripping the said flexible sheet material off the said glass paper.

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