

Aug. 18, 1959

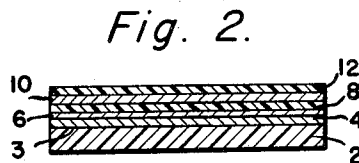
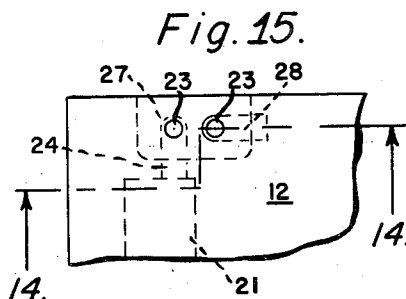
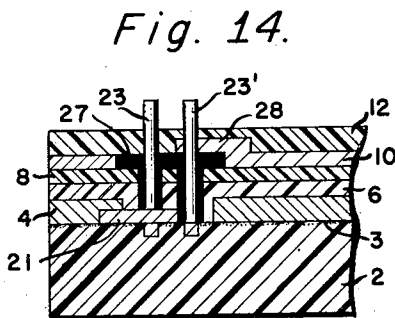
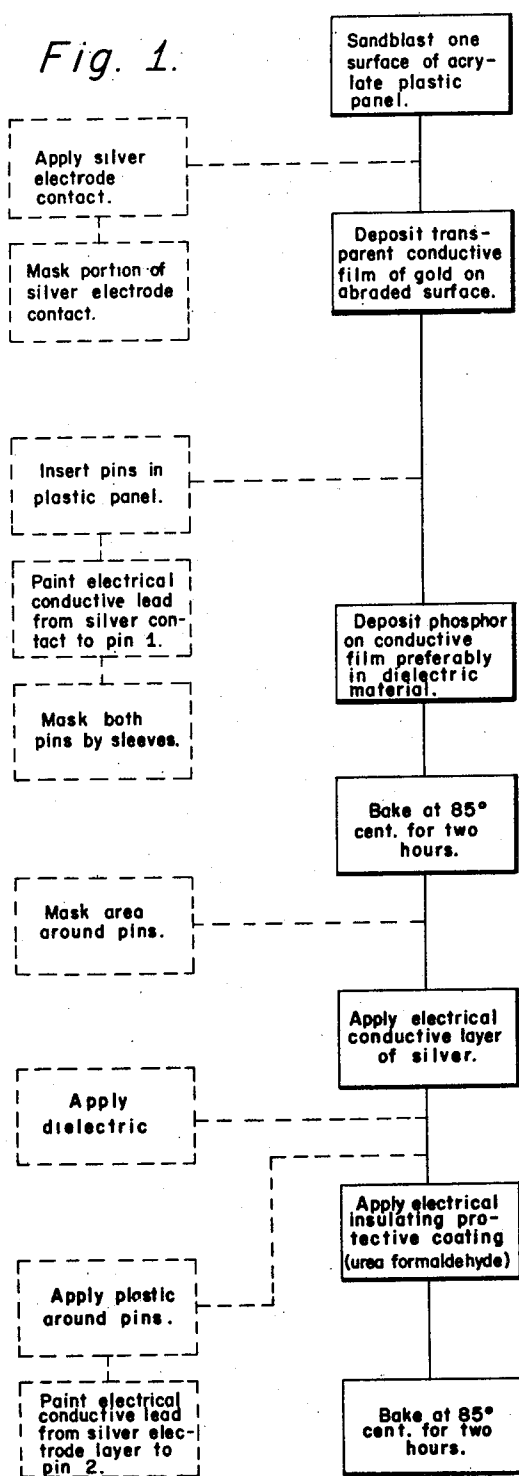
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ELECTROLUMINESCENT DEVICES AND METHODS THEREFOR

Filed July 29, 1958

2 Sheets-Sheet 1



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ELECTROLUMINESCENT DEVICES AND METHODS THEREFOR

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2 Sheets-Sheet 2

Fig. 4.

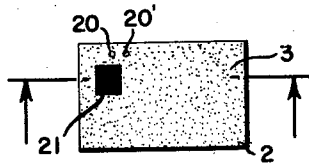


Fig. 5.

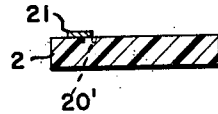


Fig. 6.

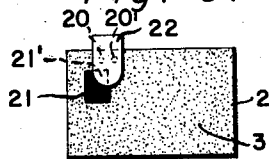


Fig. 7.

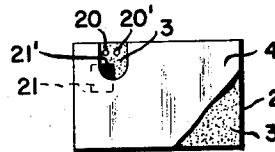


Fig. 8.

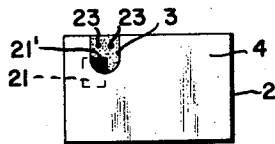


Fig. 9.

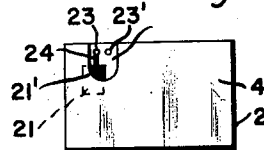


Fig. 10.

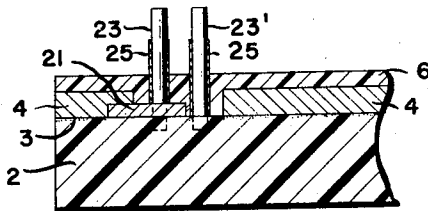


Fig. 11.

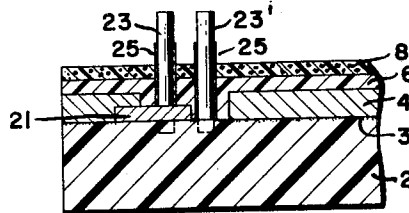


Fig. 12.

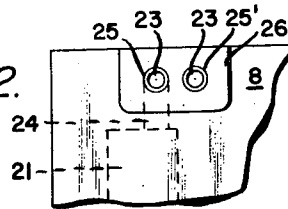
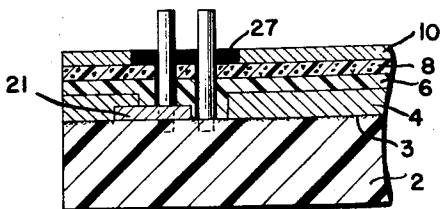


Fig. 13.



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ELECTROLUMINESCENT DEVICES AND METHODS THEREFOR

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Application July 29, 1958, Serial No. 751,746

10 Claims. (Cl. 117—33.5)

This invention relates to devices for producing the emission of light by the luminescence of a phosphor material in an alternating electric field, and to methods for the manufacture and assembly thereof. More particularly, the invention relates to electroluminescent devices in which the essential operating elements thereof are mounted on a light-transparent plastic base, and the process of manufacture thereof.

An electroluminescent device consists essentially of a light-emitting medium or phosphor disposed between two conducting electrodes, at least one of which is light-transparent and mounted in contact with a light-transparent support or base which is usually glass. The light-emitting medium usually comprises phosphor particles suspended in a dielectric medium. As noted, the base members heretofore employed were usually of glass because of the ready adherence thereto of the light-transparent electrode (usually in the form of a thin film of tin oxide) and because of the high light-transparency thereof. It is readily apparent that the structural properties of glass (i.e., strength, fragility, brittleness) leave something to be desired, especially where it is desired to provide a relatively rugged device. Understandably then, the art has been seeking a more rugged light-transparent base member for use with electroluminescent devices and a natural choice therefor has been a plastic panel. However, heretofore, great difficulty has been encountered in providing a satisfactory electroluminescent device utilizing a plastic panel because of the failure to obtain good adherence of the light-transparent electrode layer thereto.

It is therefore an object of the instant invention to provide an improved, ruggedized electroluminescent device.

Another object of the instant invention is to provide an improved electroluminescent device having a base member of plastic material.

Another object of the invention is to provide an improved method for securing a firmly-adhering light-transparent metallic coating to a light-transparent plastic base member.

Another object of the invention is to provide an improved method for manufacturing and assembling a more rugged electroluminescent device.

Yet another object of the invention is to provide an improved method for manufacturing and assembling a more rugged electroluminescent device on a plastic base member.

And another object of the invention is to provide an improved method for securing a firmly-adhering light-transparent electrode on a plastic base member for an electroluminescent device.

Still another object of the invention is to provide an improved method for securing a firmly-adhering light-transparent electrode on a light-transparent base member for an electroluminescent device.

These and other objects and advantages of the invention are achieved by forming small pits in or by roughening (as by abrading) the surface of a transparent plastic

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base member and then vapor-depositing a thin layer of metal on the roughened surface, which metallic layer may constitute the light-transparent electrode of an electroluminescent device. It will be appreciated that the step of roughening the surface of a transparent plastic body tends to degrade the light-transmissivity thereof. Unexpectedly, however, it was found that the vapor-deposited metal layer not only adhered strongly to the roughened plastic surface but that light transmission through the abraded surface and the deposited metal can be substantially restored by filling in the pits of the roughened surface with a light-transparent material applied over the metal layer. Advantageously in an electroluminescent device, this "fill" material may be a dielectric plastic per se or a dielectric plastic medium in which the electroluminescent phosphor is dispersed.

The invention will be described in greater detail by reference to the drawings wherein:

Fig. 1 is a flow chart of various steps in the method of providing an electroluminescent device in accordance with the invention;

Fig. 2 is an elevational, cross-sectional view of one embodiment of an electroluminescent panel device according to the invention;

Fig. 3 is an elevational, cross-sectional view of another embodiment of an electroluminescent panel device according to the invention;

Fig. 4 is a plan view of a panel for an electroluminescent device during an initial phase of the fabrication thereof;

Fig. 5 is an elevational cross-sectional view of the panel shown in Fig. 4;

Figs. 6-9, inclusive, are plan views of the panel of Fig. 4 during succeeding phases in the fabrication of an electroluminescent device in accordance with the invention;

Figs. 10 and 11 are elevational, cross-sectional views showing the details of a portion of the panel of Fig. 4 during further succeeding phases in the fabrication of an electroluminescent device in accordance with the invention;

Fig. 12 is a plan view of the portion of the panel shown in Fig. 11;

Figs. 13 and 14 are elevational, cross-sectional views showing the details of a portion of the panel of Fig. 2 during further succeeding phases in the fabrication of an electroluminescent device in accordance with the invention; and

Fig. 15 is a plan view of the portion of the panel shown in Fig. 14.

Referring now to Fig. 1 and particularly to those steps shown in the flow chart thereof connected by solid lines, the first step in making and assembling an electroluminescent device in accordance with the invention is to prepare the surface of a plastic panel to receive a transparent film electrode. The panel may be of any suitably transparent plastic material. An acrylic plastic such as methyl methacrylate, for example, is satisfactory. Exemplary dimensions of a panel processed according to the invention described herein are 3" x 4" x 0.187". The surface of the panel is uniformly roughened or abraded so as to be pitted. Sandblasting with a No. 300 grit sand at a pressure of about 60 pounds per square inch for about one minute is one method of providing the desired uniformly roughened surface. Another method is by chemically etching the surface of the panel with a solvent or the like. In the case of a methyl methacrylate plastic, a suitable etchant is ethylene dichloride; the etchant may be maintained in contact with the surface of the panel for about one minute in order to provide a satisfactorily roughened surface. After the surface of the panel has been suitably roughened, it is thoroughly cleaned by

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rinsing with a spray of methyl alcohol for one minute, for example, followed by a spray of distilled water for several minutes. Thereafter the panel is dried with a dry nitrogen gas stream.

It will be appreciated that this step of roughening or forming pits in one surface of the transparent plastic panel results in a severe degradation in the optical transparency of the panel. For this reason, the step of abrading the surface would appear to be a highly undesirable procedure. It was found, however, that transparent metallic films, such as gold, for example, will not adhere to smooth plastic surfaces but will adhere to a pitted or roughened surface. It was further found that such a roughened surface having such a film thereon may have a substantial amount of its transparency restored by the application of a subsequent coating or coatings of transparent film-forming material onto the transparent metallic film. These subsequently applied coatings may be either a separate dielectric plastic layer or a dielectric plastic in which the electroluminescent phosphor is suspended or dispersed. Thus, according to the present discovery, the employment of plastic panels for electroluminescent devices becomes unexpectedly feasible since good adherence of the transparent film electrode to the panel is obtained without substantially impairing the optical transparency thereof.

The next step according to the invention is to form a transparent electrically conductive layer on the clean, roughened surface of the plastic panel. This conductive film or layer may be aluminum, gold, silver, tin, or tin oxide. The process will be described with gold as a preferred example. A tungsten filament is first prepared by wrapping a wire of 24 K gold, about 4" long, therearound and heating the filament by passing electric current therethrough until the gold has melted and completely coated the filament. This filament coating operation is carried out in vacuum. Thereafter the plastic panel is placed in a vacuum chamber with the roughened surface thereof facing the gold-coated tungsten filament and spaced about 12-15" therefrom. Electrodes may be clamped to opposed edges of the panel in order to measure the surface resistivity of the panel surface during the process of depositing gold thereon. The gold-coated tungsten filament is then energized again with electric current to vaporize the gold which is deposited upon the roughened surface of the plastic panel until the measured surface resistivity thereof is about 100 ohms, for example.

After removing the panel from the vacuum chamber, an electroluminescent coating is applied over the deposited gold film surface to a thickness of about 3 mils ± 0.1 . The electroluminescent coating is formed by spraying an electroluminescent phosphor powder disposed in an inorganic dielectric binder onto the gold film electrode. A suitable spray formulation comprises about 2 parts by weight of phosphor powder thoroughly mixed with about 5 parts by weight of urea formaldehyde, thinned to spraying consistency with toluene-isopropyl alcohol in equal parts. The phosphor may be a manganese-activated zinc sulfide yellow phosphor identified as Du Pont No. Q96-3253 and sold by E. I. du Pont de Nemours and Company, Wilmington, Delaware.

Alternatively, a separate dielectric layer of urea formaldehyde may be first formed on the gold film electrode by spraying and then the phosphor-carrying electroluminescent dielectric layer may be sprayed thereon in order to achieve a greater degree of electrical insulation between the phosphor material and the electrode layer. Such enhanced insulation is especially desirable where it is intended to employ relatively high voltage gradients across the electroluminescent layer. In either instance, the coated panel is then baked at about 85° C. for about 2 hours in order to drive off the solvents and cure and harden the layer or layers.

A second electrode layer is then formed over the electroluminescent layer by spraying silver paint there-

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over to a thickness of about 4 mils ± 0.5 . The silver paint may be thinned to spraying consistency by mixing with equal parts of toluene-isopropyl alcohol. Thereafter the panel is dried in air at room temperature for about ½ hour and then baked for about 2 hours at 85° C. in a dust-free container.

The silver electrode layer is coated with a dielectric layer by spraying urea formaldehyde thereover as before. Urea formaldehyde of suitable spraying consistency is prepared by thinning two parts thereof with one part of toluene-isopropyl alcohol. The panel is then air-dried for about ½ hour and baked in a dust-free container for about 2 hours at about 85° C. and is then ready for use.

Referring now to Fig. 2, an electroluminescent device utilizing a plastic panel 2 prepared and assembled according to the invention and having a roughened surface, indicated by reference numeral 3, is shown. A transparent conductive electrode layer 4, formed according to the process just described, firmly adheres to the roughened surface 3 and cooperates therewith to provide transmission of light through this surface at a relatively high value. In contact with the electrode layer 4 is a dielectric layer 6 which is incorporated therein in order to permit the device to be operated with relatively high voltage gradients (i.e., 900 volts) across the electroluminescent layer. The phosphor or electroluminescent layer 8 is in contact with the dielectric layer 6 and an electrode layer 10 is superimposed over the electroluminescent layer. The electrode layer 10 is coated with an insulating layer 12 of urea formaldehyde, for example.

In Fig. 3 an alternative embodiment of an electroluminescent device according to the invention is shown which omits the dielectric layer 6 between the electroluminescent layer 8 and the transparent conductive electrode layer 4. Such an arrangement is useful and desirable for applications wherein the voltage gradients to be employed across the electroluminescent layer 8 are relatively small (i.e., less than 125 volts).

Referring now to Fig. 1, particularly including the steps connected by dash lines, and to Figs. 4-15, an electroluminescent device assembled according to the invention is shown having pin connections to the electrode layers mounted perpendicularly in the plastic base and passing through the various layers of the device as shown. Such pin electrode connections are highly desirable and convenient but difficult to provide since the pins must be electrically insulated from each other and from the electrode layers through which they pass except for the layer to which each pin is to be in good electrical contact. The panel is provided with a pair of holes 20, 20' drilled therein to receive the pins. After the surface 3 of the panel has been sandblasted and cleaned as described heretofore, a small area 21 thereof near the pin holes is painted with silver paste, as shown in Figs. 4 and 5. The purpose of the area 21 is to ensure good electrical contact with the gold layer electrode when applied thereover and on the roughened surface of the panel. A small portion 21' of the silver area 21 is then masked by a metal tab 22, as shown in Figs. 6 and 7. The gold electrode layer 4 is then vapor deposited over the entire surface as described previously. Thereafter the metal tab mask 22 is removed. At this point the entire surface of the panel is coated with the transparent conductive gold layer 4 except for a small portion 21' of the silver area and the pin area as shown in Figs. 7 and 8. A pair of goldplated brass pins 23, 23' are then inserted into the pin holes and the exposed portion of the silver area is electrically connected to one of the pins by painting a path 24 thereto and around with an electrically conductive silver paint as shown in Fig. 9. Sleeve type masks 25, 25' are then slipped over both of the pins and a dielectric material 6 is applied over the entire surface of a panel, as described previously. The details of the pins and the panel at this particular point

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in the process are shown in Fig. 10. The electroluminescent layer 8 is then applied over the entire surface as shown in Fig. 11 and as described previously. The entire area around the pins is then masked with a metal tab 26 as shown in Fig. 12 and the silver electrode layer 10 is then formed by spraying the entire surface as described heretofore. The panel at this stage of the process is shown in Fig. 13. The tab mask 26 and the sleeve masks 25, 25' are then removed and an electrically insulating plastic material 27 such as epoxy resin is applied to the area around the pins and allowed to flow down into the wells established around the pins by the sleeve mask as shown in Fig. 13. An electrical connection 28 is then made from the silver electrode layer 10 to the second pin 23' by painting a conductive path therebetween with silver conductive paint over the epoxy resin layer 27. Thereafter a dielectric coating 12 is applied over the entire surface as described previously. The completed device and its details are shown in Figs. 14 and 15.

It will be appreciated that this manner of mounting the pins provides each pin with a substantial electrically insulating envelope or sleeve which greatly reduces the likelihood of voltage breakdown or arcing between the pins and the electrode layers.

There thus has been described a novel and useful method for manufacturing an electroluminescent device utilizing a plastic panel. It will be appreciated that variations in the practice of the invention may be made without departing from the spirit thereof.

What is claimed is:

1. The method of providing a light-transparent plastic member with a firmly-adhering transparent metallic film comprising the steps of: roughening a surface of said plastic member whereby the optical transparency thereof is reduced, vapor-depositing a light-transparent metal layer onto said roughened surface, and rendering said roughened surface substantially smooth by applying a light-transparent material over said metal layer.

2. The method according to claim 1 wherein said surface is roughened by sandblasting, and said metal layer is gold.

3. The method of manufacturing and assembling an electroluminescent device comprising the steps of: roughening a surface of a plastic base member, vapor-depositing a light-transparent electrode onto said roughened surface, disposing an electroluminescent phosphor material dispersed in a light-transparent dielectric medium adjacent said light-transparent electrode, and disposing a second electrode adjacent said electroluminescent material dispersed in said dielectric medium.

4. The method of manufacturing and assembling an electroluminescent device comprising the steps of: roughening a surface of a plastic base member, forming

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a light-transparent electrode layer on said roughened surface of said base member, applying a layer of an electroluminescent phosphor material dispersed in a dielectric medium in contact with said light-transparent electrode layer, and forming a second electrode layer adjacent said layer of electroluminescent material dispersed in said dielectric medium.

5. The method according to claim 4 wherein said light-transparent electrode layer is formed by vapor-depositing a thin film of metal onto said roughened surface.

6. The method according to claim 5 wherein said surface of said plastic base member is roughened by sandblasting, and said metal is gold.

7. In the manufacture and assembly of an electroluminescent device, the steps of providing a light-transparent electrode on a plastic base member for said device by roughening a surface of said base member, vapor-depositing a light-transparent film of metal thereon, and restoring a substantial degree of smoothness to said roughened surface by covering said light-transparent film of metal with a light-transparent film-forming material.

8. An electroluminescent device comprising a substantially light-transparent plastic base member having a roughened surface, a light-transparent metallic electrode layer firmly secured to said roughened surface, an electroluminescent phosphor material dispersed in a dielectric medium adjacent said light-transparent electrode, and a second electrode layer adjacent said phosphor material dispersed in said dielectric medium.

9. An electroluminescent device comprising a substantially light-transparent plastic base member having a roughened surface, a light-transparent metallic electrode layer firmly secured to said roughened surface, an electroluminescent phosphor material dispersed in a dielectric medium in contact with said light-transparent electrode, and a second electrode layer adjacent said phosphor material dispersed in said dielectric medium.

10. An electroluminescent device comprising a substantially light-transparent plastic base member having a roughened surface, a light-transparent metallic electrode layer firmly secured to said roughened surface, a light-transparent dielectric coating in contact with said light-transparent metallic electrode layer, an electroluminescent phosphor material dispersed in a dielectric medium adjacent said light-transparent dielectric coating, and a second electrode layer adjacent said phosphor material dispersed in said dielectric medium.

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