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ELECTROLUMINESCENT PRINTED CIRCUIT DISPLAY

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2 Sheets-Sheet 1

FIG. 1

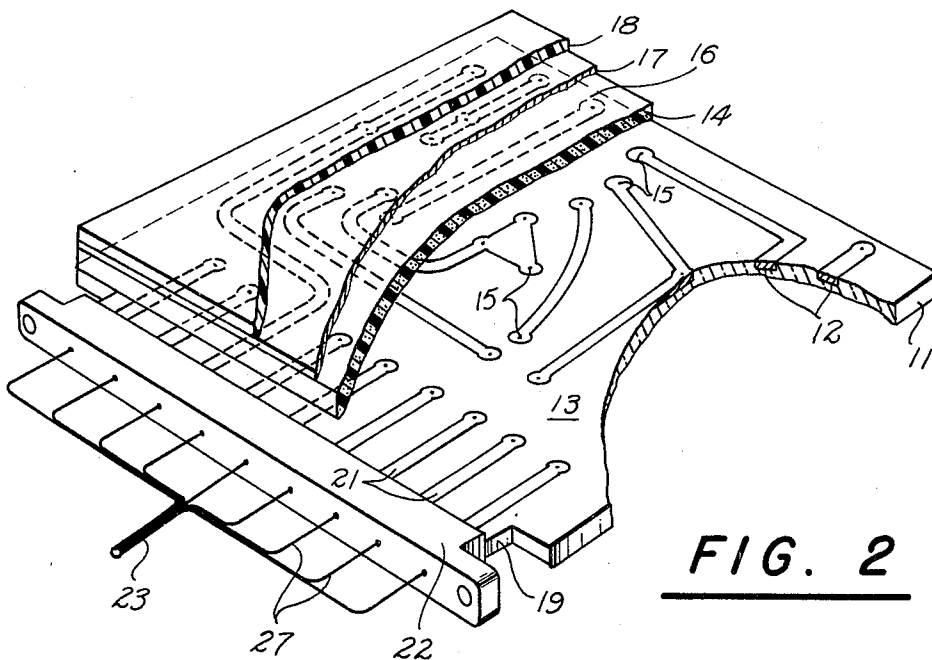
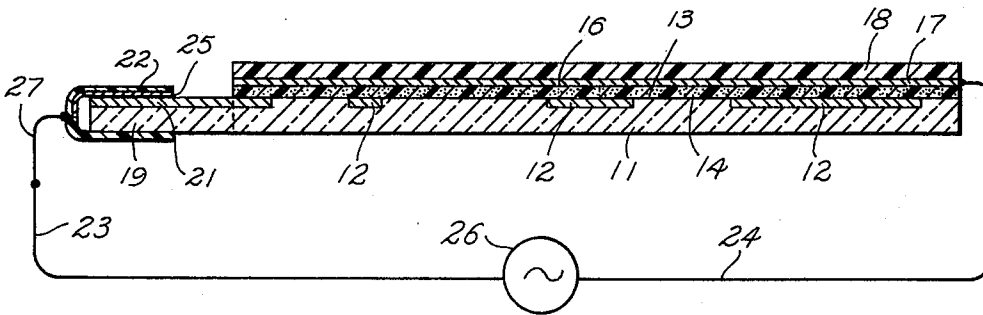


FIG. 2

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ELECTROLUMINESCENT PRINTED CIRCUIT DISPLAY

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4 Claims. (Cl. 315-246)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an electroluminescent device and more particularly to an electroluminescent device which provides a visual, light-defined display of the electrically-active portions of an electrical circuit network.

The present invention is an integral, rugged structure which, in essence, incorporates the working combination of a "printed (electrical) circuit" and an electroluminescent lamp which coact in such a fashion that the light-emitting phosphor material of the electroluminescent lamp is discriminately actuated to produce a pattern of light excitation which gives a continuous visual representation of the electrically-active portions of the "printed circuit" part of the combination. An electroluminescent lamp (or cell, as it is sometimes called) consists basically of a phosphor material embodied in a dielectric layer which in turn is sandwiched between a pair of electrode layers. A pulsating electrical potential is applied across the electrode layers to excite the interposed phosphor material to electroluminescence. In the present device, the discriminative actuation of the phosphor material of the electroluminescent lamp embodied in the device is accomplished by the use of the electrically-active portions of the "printed circuit" part of the device as one of the actuating electrodes. This "printed circuit" electrode, situated on one side of the phosphor material, coacts with an electrode layer situated on the other side of the phosphor material to produce luminescence in the phosphor material only where the phosphor material is sandwiched between an electrically-active portion of the printed circuit and the corresponding oppositely-located portion of the electrode layer. The light thus created in the phosphor material is then appropriately passed to the viewable face of the electroluminescent lamp where it defines a light pattern which traces out the electrically-active portion of the underlying printed circuit. The resulting electroluminescent device can be employed, among other uses, to show operability of an electrical circuit, to pinpoint sources of trouble or non-function in such a circuit or as a training device in instruction relating to electrical circuitry. This integral-unit device of the invention is noteworthy for a significantly superior functional quality and ruggedness.

Among objects of importance of the present invention are the following:

To provide an electroluminescent device which provides a light-defined visual display delineating the electrically-active portions of an electrical network.

To provide an electroluminescent device of marked ruggedness in its structure.

To provide a device which enables trouble or non-function in a circuit to be visually discernible.

To provide a training device for instruction in electric circuitry.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawing in which:

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FIG. 1 is an elevational view, partly in section, of a preferred embodiment of the invention;

FIG. 2 is a perspective view, partly broken away, of the preferred embodiment of FIG. 1;

FIG. 3 is an elevational view, partly in section, of an alternative embodiment of the invention; and

FIG. 4 is a perspective view, partly broken away, of the alternative embodiment of FIG. 3.

Attention is initially directed to the preferred embodiment of the invention which is represented in FIGS. 1 and 2 of the drawing. The structure of the electroluminescent device involved will be defined more or less in terms of the method by which it is constructed.

A dielectric substrate 11 has embedded therein an electrically-conductive metal pattern 12 which defines the conducting paths of an electrical network. This dielectric substrate 11 and metal pattern 12 are the main elements of what has been referred to above as a "printed circuit." In constructing the "printed circuit" a thin metal sheet is cemented to the substrate 11 which may be an epoxy fiberglass. Then by photo-etch, or similar process, the desired circuit pattern is produced from the metal sheet by subtracting from the metal sheet all but the desired metal lines which are to define the metal circuit pattern 12. The metal circuit pattern 12 is then pressed into the substrate 11 so that the top surface of the metal circuit pattern 12 is flush with the top surface 13 of the substrate 11. In the particular embodiment defined herein metal circuit pattern 12 was hot pressed into substrate 11 at a temperature of 350° and at 2,000 pounds per square inch pressure. The combination was then cooled, still under pressure and then cleaned by manual scrubbing with a suitable cleanser or by the use of a suitable chemical wash. More efficiency in light output from the electroluminescent device (in a manner to be dwelled upon later infra) can be attained by then polishing the top surface of the metal pattern 12 or plating this top surface of the metal pattern 12 with a highly reflective material such as silver. Generally the metal pattern 12 will be formed of copper.

Various external circuit elements can be connected into the circuit network delineated by metal pattern 12 by boring appropriate holes (through the underside of dielectric substrate 11) by means of which electrical leads (connected to the various external circuit elements) can be brought to and soldered to the selected points in the metal pattern 12. Points 15 seen on metal pattern 12 are points at which this metal pattern 12 is adapted to connect to such external circuit elements by way of leads brought up through substrate 11 and soldered to pattern 12 at the selected points 15. Any rough spots produced by the soldering operation should be smoothed down to preserve the smooth upper surface of the combination of dielectric substrate 11 and the electrically-conductive metal pattern 12 embedded therein.

A highly concentrated mixture of electroluminescent phosphor and a transparent resin binder material is sprayed onto the upper surface of the plate (or "printed circuit") consisting of the dielectric substrate 11 and the metal pattern 12 embedded therein. The result is the dielectric-phosphor layer 14 which is a dielectric layer containing a high concentrate of electroluminescent phosphor. The phosphor employed is any conventional electroluminescent phosphor (such as, for example, the well-known zinc sulfide activated by copper and coactivated by chlorine). A preferred embodiment for this dielectric binder of the dielectric-phosphor layer 14 is high molecular weight polyurethane. The mixture of binder and phosphor must be applied as a "wet" layer in order that the dielectric-phosphor layer 14 be characterized by a very smooth, almost "glassy" upper surface 16. (The

reason for this requirement will be dwelled upon later.) Though dielectric-phosphor layer 14 is preferably formed by spraying, it also may be formed by "roller coating" the appropriate mixture upon the underlying substrate 11 and metal pattern 12 combination.

After the dielectric-phosphor layer 14 has "hardened" in place, a transparent or translucent conductive coating is then applied to the upper very smooth surface 16 of the dielectric-phosphor layer 14 to form thereupon the transparent conductive layer 17. This conductive layer 17 is formed of metal such as gold, silver, or aluminum which is deposited by vapor deposition under vacuum to achieve a very thin layer of the metal concerned. Achieving sufficient thinness in this metal conductive layer 17 is very important to the transparency/translucency of this layer 17 and effective operation of the luminescent device of the invention. It is the very smooth upper surface 16 of the dielectric-phosphor layer 14 upon which conductive layer 17 is vapor-deposited that permits the achievement of this thinness in the conductive layer 17. Since any of the metals involved are, per se, opaque it is very necessary to obtain this thinness in conductive layer 17 in order that adequate transparency/translucency be achieved. This transparency/translucency in conductive layer 17 is important because the light emitted from dielectric-phosphor layer 14 is to pass via this conductive layer 17.

A transparent dielectric coating is then sprayed over the conductive layer 17 to protect the conductive layer 17 and to seal what, in effect, is the "electroluminescent lamp" portion of the invention. This protective dielectric coating is relatively heavy and preferably consists of a moisture-resistant, abrasion-resistant, transparent coating material such as polyurethane. In addition to being sprayed onto the underlying conductive layer 17, such coating can be "brushed on" or "flowed onto" conductive layer 17 and this coating when cured will form the protective dielectric layer 18.

Metal pattern 12 is connected in a conventional manner to an electrical lead 23 and transparent conductive layer 17 in a conventional manner to another electrical lead 24. These electrical leads 23 and 24 lead respectively to the opposite sides of a source of pulsating voltage 26 which imposes a pulsating voltage between metal pattern 12 (acting as the one electrode of the "electroluminescent lamp") and conductive layer 17 (acting as the other electrode of the "electroluminescent lamp").

FIGS. 3 and 4 portray an alternative embodiment of the invention which differs from the FIGS. 1 and 2 embodiment to the extent that in this alternative embodiment it is not requisite that the upper surface of metal pattern 12' be flush with the upper surface 13' of dielectric substrate 11', but only that the metal pattern 12' be sandwiched between the dielectric substrate 11' and the dielectric-phosphor layer 14. In the representative showing in FIGS. 3 and 4 of this embodiment metal pattern 12' is caused to adhere to dielectric substrate 11'. It may be partially embedded therein. It can also be fastened to dielectric substrate 11' without being embedded therein to any degree. Metal pattern 12' is thus shown in FIGS. 3 and 4. It readily can be seen why the embodiment in the FIGS. 1 and 2 showing is the preferred embodiment. The thickness of the dielectric-phosphor layer 14 is a parameter of the light output from the electroluminescent device disclosed herein. In a particular embodiment of the electroluminescent device which does not have its metal pattern embedded in the dielectric substrate with the upper surface of the metal pattern flush with the upper surface of the dielectric substrate, when the dielectric-phosphor coating is applied over the combination of the dielectric substrate and conductive metal pattern, there will be a tendency for the applied coating to form "humps" or "ridges" above the location of the various portions of the conductive metal pattern. The result is a dielectric-phosphor layer which is uneven and

distorted. This distortion in the dielectric-phosphor layer causes undesirable brightness variation in the light emerging from the electroluminescent device. Moreover, this lack of uniformity in the lower portion of the dielectric-phosphor layer translates into a lack of uniformity in the upper portion of the dielectric-phosphor layer which multiplies the difficulty in obtaining a uniform metal conductive layer atop the dielectric-phosphor layer which, as is noted above, is so important to the achievement of the requisite transparency/translucency in this metal conductive layer.

It will be noted that the printed circuits of both the preferred and alternative embodiments of the invention are provided with a border 19 which has a series of conductive metal leads 21 running therealong which run to the operative portion of the printed circuit. This border 19 with its portions of metal leads 21 can be formulated as an integral extension of the substrate structure of the operative printed circuit, but is not a part of the "printed circuit," "electroluminescent lamp" operative combination. It merely serves as a convenient way of establishing external electrical connection with the "printed circuit," these conductive metal leads 21 being adapted to mate with corresponding leads 25 carried by a female socket 22 which is adapted to embrace the border 19 as shown in the drawing and which is of a type conventionally used for making electrical contact with "printed" circuits. The various electrically-conductive leads 25 of socket 22 are positioned at such spaced intervals from one another that, when socket 22 is in operative registry with border 19, each metal lead 21 will be in mating registry with a given one of these socket leads 25. Each of socket leads 25 is individually connected to electrical lead 23 by way of an electrical lead 27. Various external circuit elements can also be positioned anywhere along the paths of these individual electrical leads 27.

OPERATION

From voltage source 26, which is connected, on the one hand, to metal circuit pattern 12 via lead 23, the various leads 27 and socket 22 and, on the other hand, to transparent conductive layer 17 via lead 24, an appropriate phosphor-actuating electrical signal is impressed across dielectric-phosphor layer 14. The whole of transparent conductive layer 17 will be activated by the impressed signal. This impressed signal derived from voltage source 26 also provides the necessary activating E.M.F. for the "printed circuit" portion of the device and only that portion of metal circuit pattern 12 which is electrically-active will act as a cooperating operative electrode with transparent conductive layer 17 for the purpose of activating phosphor material in the dielectric-phosphor layer 14. The result is that the electrically-active portion of metal pattern 12 acts as a spatially discriminating electrode to cause dielectric-phosphor layer 14 to selectively luminesce to define a light pattern which is coincident in form with the underlying electrically-active portion of metal pattern 12. Thus, for example, if any portion of a desired printed circuit configuration should become inoperative for any reason, the circuit path involved would fade out of the total light pattern produced in dielectric-phosphor layer 14 (by the underlying electrically-active part of the metal pattern 12 involved). This "fade-out" would provide an instant indication of the "loss" of an operative portion of the underlying printed circuit. The light pattern produced in dielectric-phosphor layer 14 will readily transmit itself through transparent conductive layer 17 and protective dielectric layer 18 to be clearly visible to an observer. As previously noted, it is the extreme thinness of metal conductive layer 17 that provides this layer its necessary operative transparency. The polishing or plating of the top surface of metal pattern 12 with a highly reflective material improves the efficiency of the light output of the electroluminescent de-

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vice. In addition to showing operability or non-operability of various parts of the "printed circuit" underlying the dielectric-phosphor material, it can be seen that the invention device can be used readily as a training device for demonstrating the workings of electrical networks by means of the light-defined pattern derived therefrom.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is intended to cover all changes and modifications which may be made without departing from the spirit and scope of this invention.

What is claimed is:

1. An electroluminescent device adapted to be coupled to external electrical circuit elements for displaying the operative condition of said elements, comprising:

- (a) a translucent electrically-conductive electrode layer;
- (b) an electroluminescent dielectric-phosphor layer underlying said translucent electrically-conductive electrode layer;
- (c) printed circuit electrode means underlying said electroluminescent dielectric-phosphor layer, said means including a dielectric material layer and a printed circuit pattern carried by said dielectric material layer;

said printed circuit pattern including a plurality of electrically conductive members spaced in an electrically-insulated disposition one from the other, and electrical leads operatively coupled to each member for permitting independent energization of each member, said leads extending externally of said dielectric-material layer for enabling said members to be electrically coupled to said external electrical circuit elements whereby an electrical circuit can be completed

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through said elements and said printed circuit pattern for energizing said pattern members,

(d) a source of pulsating voltage, and

(e) means electrically coupling one pole of said source to at least one of said conductive members and the other pole to said electrically-conductive electrode layer for producing a luminescence having a pattern dependent upon the operative condition of said externally-coupled circuit elements.

2. The device of claim 1 further including a translucent dielectric-material layer overlying said electrically-conductive electrode layer.

3. The device of claim 1 wherein said pattern is embedded in said dielectric-material layer with its upper surface flush with the upper surface of said dielectric-material layer, the upper surface of said dielectric-material layer being that surface thereof which is proximate to said dielectric-phosphor layer.

4. The device of claim 3 wherein said pattern members are formed of metal strips, said leads being coupled to terminal ends of the strips and extending externally of said device through said dielectric-material layer.

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