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(54) **Electroluminescent device and its manufacture.**

(57) Electroluminescent devices are advantageously made by forming between suitable conductive layers a printed dielectric layer and a printed phosphor layer, preferably using an ink comprising solvent-free UV-curable binder in which the high dielectric solid or the phosphor is dispersed. Such layers are formed in a much simpler manner than the corresponding layers in previously known electroluminescent devices.

Description

ELECTROLUMINESCENT DEVICE AND ITS MANUFACTURE

This invention relates to electroluminescent devices, and in particular to electroluminescent lamps useful in point of sale displays, and to their manufacture.

Electroluminescent lamps consist essentially of a thin layer of a phosphor in a dielectric matrix sandwiched between two conductive layers of which at least one is transparent or translucent. Normally, the lamp also comprises a dielectric layer between the phosphor layer and one of the conducting layers, usually the opaque conductive layer if there is only one transparent or translucent conductive layer. The phosphor layer typically consists of a dispersion of zinc sulphide in a binder having the required dielectric properties, and the dielectric layer consists of a dispersion of a high dielectric material such as barium titanate in a suitable binder. In the known electroluminescent lamps, the dielectric binder is usually cyanoethyl cellulose which may be plasticized, e.g. with cyanoethyl phthalate. The phosphor layer is sensitive to moisture and the known electroluminescent lamps are therefore normally enclosed in an encapsulating envelope of a thermoplastic material which is highly impervious to moisture. Assemblies of this kind are described in numerous patent specifications, e.g. United States Patent Nos. 2951865, 3346757 and 3395058.

It is a major disadvantage of the known electroluminescent lamps that they are complicated and therefore expensive to manufacture. The lamps which are commercially available at the present time use cyanoethyl cellulose as the binder in the phosphor and dielectric layers. Cyanoethyl cellulose is chosen for its relatively high dielectric constant of 10 to 20 since the layers must have as high a dielectric constant as possible in order to concentrate the electrical energy applied across the phosphor layer. If a binder of lower dielectric constant were used the brightness of the lamp (i.e. efficiency of utilisation of the electric field) would be reduced.

However, the manufacture of known electroluminescent lamps is accompanied by serious disadvantages. In particular the phosphor and dielectric layers are applied, typically by blade or reverse roller coating, as dispersions of the finely divided solids in a solution of the cyanoethyl cellulose. Consequently, the solvent must be removed from each layer before a subsequent layer can be added. This involves baking each layer for ten to ninety minutes. In addition, the formation of the encapsulating layers is an additional expensive and time consuming operation.

It is a further major disadvantage of the known lamps that moisture ingress into the Barium titanate/Phosphor/Indium tin conductive layer reduces the life of the lamp and results in the formation of dark spots, large unlit areas of illumination and finally electrical breakdown of the lamp structure. In order to prevent these, the lamps are often encapsulated in a highly impervious thermoplastic material such as

Aclar which incorporates a moisture barrier such as Caplan. This Aclar/Caplan configuration has however several disadvantages:

- (1) it is relatively expensive;
- (2) it must be vacuum/heat formed;
- (3) Aclar tends to crack after a period of time and then allows moisture ingress;
- (4) the electrical connections must penetrate the Aclar which provides a point of moisture ingress/mechanical weakness;
- (5) the encapsulation technique requires high temperatures (ca. 110°C) which limit the substrate on which the lamp layers can be fabricated; and
- (6) the encapsulation of the lamp introduces a second manufacturing procedure which is time consuming and costly.

A further disadvantage of current methods of making electroluminescent lamps is that they do not lend themselves to the production of laminates having complicated shapes. Furthermore, customary methods can only be easily be operated if the layers are successively applied to the opaque conductive layer which acts as substrate. It is difficult or impossible to apply the layers successively to a cheap transparent plastic substrate, i.e. to deposit the layers in the reverse order.

We have now discovered that these disadvantages of the prior art may be avoided and the manufacture of electroluminescent devices greatly simplified and cheapened by applying the phosphor layer and the dielectric layer by printing, especially screen-printing, using as binder a standard printing ink binder. The new method is simpler and cheaper to operate than the known methods and uses standard printing ink formulations.

In a preferred embodiment of the invention, the ink binder is a UV-curable resinous binder. The preferred UV-curable binders contain little or no solvent to be removed after deposition of the layer, and they are very rapidly dried (cured) by exposure to an appropriate ultra-violet lamp. Further, because such binders contain no solvent, the solids content of the layer can be substantially increased so that efficiency of operation of the device is improved. Such binders cure to provide layers having, without encapsulation, excellent moisture resistance.

Alternatively, in accordance with another preferred way of operating the invention, UV curable overlacquer may be applied over moisture sensitive printed layers to combat moisture ingress. While with UV-curable inks the effects of moisture are negligible, with conventional inks, the addition of a UV-cured lacquer provides the necessary protection against moisture. In place of a UV-curable overlacquer, a modified silicone conformal coating (equivalent to manufacturers grade ACC3) can also be used to reduce moisture derived degradation. This coating can be sprayed or silk screened or bath coated on to a lamp to produce a protective coating which meets the specifications BS3G100 and MIL STD 810

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Any such overlacquer must be:

- (1) Moisture-impermeable and electrically non-conducting;
- (2) sufficiently hard to protect the underlying lamp layers and prevent loss of conductivity of the Indium Tin layer;
- (3) capable of application by Silk Screen/Roller printing techniques for sheet and web substrate systems;
- (4) capable of providing a surface finish which allows the printing of face colours onto the lit or unlit area of the lamp, to allow information to be illuminated/displayed, and
- (5) capable of bonding well to the substrate to prevent cracking when the lamp is flexed.

When the layers are formed by screen printing a fairly coarse mesh (e.g. 21T) may be used with solvent-containing formulations, but with the preferred UV-curable inks a finer mesh (e.g. 90-140T) gives a more uniform layer.

The present invention accordingly provides an electroluminescent device comprising: a printed dielectric layer comprising a binder having a finely divided solid of high dielectric constant dispersed therein; a printed light generator layer adjacent to said dielectric layer and comprising a binder having a finely divided solid phosphor dispersed therein; and two electrically conductive outer layers of which at least the layer adjacent to the light generator layer is transparent or translucent. Normally, the device also includes a support layer which may be either adjacent to the opaque electrically conductive outer layer, in which case the substrate may be opaque also, or (usually less desirably) adjacent to the transparent or translucent electrically conductive outer layer in which case the substrate must be transparent or translucent also.

When UV-cured resinous binders are used in the printed layers, the sensitivity to moisture of the various layers, and especially the phosphor layer, is greatly reduced and it is then unnecessary to encapsulate the electroluminescent device unless very long operating life is required. For many purposes, and in particular for point of sale displays, long life is not necessary. A point of sale display typically is used for only a few weeks and is then discarded. Known electroluminescent devices are much too expensive to be used for such short periods, but the devices of the invention can be cheaply made and are very suitable for this use.

The electroluminescent devices of the present invention are made by successively printing, on to an electrically conductive layer, layers of ink having dispersed therein, respectively either a finely divided solid of high dielectric constant or a finely divided solid phosphor, and applying to the second printed layer a second electrically conductive outer layer. When, as is preferred, the inks comprise a UV-curable binder, each printed layer containing such binder is cured by exposure to actinic radiation before the next layer is applied. A single layer may be formed by repeated printing if so desired, e.g. to give a thicker layer.

The electrically conductive layers used in the

devices of the present invention may be the same as those used in known devices. Thus the opaque layer which may also act as support may be made of aluminium foil or another conductive metallic sheet material. Alternatively or in addition, it can be advantageous to print a silver-containing or other conductive ink onto the support to form an opaque electrically conductive layer. The transparent or translucent electrically conductive layer is usually an indium/tin oxide layer as in the known devices, as this material provides the necessary combination of conductivity and transparency. Other transparent conductors, e.g. a vacuum deposited gold/aluminium/silver/indium layer could in principle be used but are likely to be more expensive.

The phosphor used in the phosphor layer is preferably activated zinc sulphide as in known devices. Other phosphors could be used, e.g. for particular colour effects. The solid of high dielectric constant is preferably barium titanate though in principle other high dielectric finely divided solids could be used.

The preferred UV-curable binder is a known material currently used in ultra violet curable inks, e.g. for screen printing. For the purposes of the present invention the binder is used in the form of a pigment-free and solvent-free varnish into which the phosphor or the dielectric solid (as the case may be) is ground. The proportion of the finely divided solid in the binder is preferably 30 to 60% of the total weight of solid and binder. This proportion is the same in the uncured ink before application and in the cured layer.

The solvent free varnishes used in the present invention usually contain an ethylenically unsaturated low molecular weight polymer dissolved in an ethylenically unsaturated liquid monomer together with suitable polymerization initiators to promote polymerization under the influence of ultra violet light and often polymerization inhibitors to prevent polymerization initiated in other ways and thus prolong the shelf life of the varnish. These varnishes are well known in the art and do not require detailed description.

The layers in the electroluminescent devices of the present invention are formed by printing which is rapid and easily controllable. Prior art electroluminescent devices have often been made using doctor blade or reverse roller coating techniques which require substantially more complicated apparatus. Preferably an electroluminescent device in accordance with the invention is made by successive printing on a suitable substrate of the various required layers, each of which is usually 5 to 60 microns thick. It is a significant practical advantage of the present invention that the substrate may be, for example, either an opaque card or a transparent or opaque plastics sheet.

In a typical preferred embodiment of the invention, a non-conductive support sheet, e.g. of card, is successively printed, by screen printing, with the following layers:

- (1) An electrically conductive layer of a silver based ink 5 to 10 microns thick;
- (2) A layer of about 30 to 60% finely divided

barium titanate in 70-40% of a UV-curable resinous varnish, about 20 to 40 microns thick;

(3) A layer of activated finely divided zinc sulphide dispersed in a UV-curable resinous varnish in the proportions of about 30 to 60% zinc sulphide to 70-40% varnish, about 30 to 60 microns thick; and

(4) A layer of electrically conductive indium/tin oxide which is transparent and about 5 to 10 microns thick. Layers (2) and (3) are each cured by exposure to UV-light before the next layer is applied.

Suitable silver conductors are applied to the indium/tin oxide layer. When this device is energized by application of an electric current, e.g. 200 milliamps at 110 volts and 400 Hz, the phosphor is caused to emit light which is visible through the indium/tin oxide layer. As indicated, all the layers in this device apart from the support layer itself can easily be applied using ordinary printing techniques and the UV-curable varnish binders can be very rapidly cured (within 2-3 seconds) using banks of ultra-violet lamps in the usual way. The device is thus exceptionally rapid to make. Moreover the shape and configuration of the device can be in any desired form compatible with use of the chosen printing method.

If desired, the card support may be replaced by a transparent plastics sheet support in which case the layers may, if required be applied in the reverse order.

A final layer of overlacquer may be printed on to the outside or one or both of the support sheet and the conductive indium-tin layer in order to provide improved moisture resistance. This is especially desirable when the printed layers are formed using binders which are moisture sensitive. Such overlacquers may be made of the same UV-curable varnishes as those which can be used in making the layers of the lamp, e.g. those sold under the trade names Uviplast, Uvispeed and Uvibond (Sericol), Viospeed (Coates), and Solascan varnish (Danes).

The final structure may if desired be overprinted, e.g. with the desired message for the point of sale device. Any such overprinting, like the support itself and any overlacquer layer should be electrically non-conductive and preferably non-arcing.

The silver-based ink may be replaced, if desired, by a carbon-based conductive ink but this gives a less bright lamp as the carbon-based ink is black.

Claims

1. An electroluminescent device comprising: a printed dielectric layer comprising a binder with a finely divided solid of high dielectric constant dispersed therein; a printed light generator layer adjacent to said dielectric layer comprising a binder having a finely divided solid phosphor dispersed therein; and two electrically conductive outer layers of which at least the layer adjacent to the light generator layer is transparent or translucent.

2. An electroluminescent device according to

claim 1 in which the solid of high dielectric constant is barium titanate.

3. An electroluminescent device according to claim 1 or 2 in which the phosphor is activated zinc sulphide.

4. An electroluminescent device according to any one of claims 1 to 3 which is provided on one or both outer layers with a moisture-resistant overlacquer.

5. An electroluminescent device according to any one of claims 1 to 4 in which the said binder in the said dielectric layer and/or light generator layer and/or any overlacquer layer is a UV-cured resinous binder.

6. An electroluminescent device according to any one of claims 1 to 5 in which the transparent or translucent electrically conductive outer layer is an indium/tin oxide layer.

7. An electroluminescent device according to any one of claims 1 to 6 in which each of the dielectric layer and the light generator layer contains 30 to 60% of finely divided solid dispersed in the binder, the said percentage being based on the total weight of the layer.

8. An electroluminescent device according to any one of claims 1 to 7 in which the dielectric layer and the light generator layer are each 20 to 60 microns thick.

9. An electroluminescent device according to any one of claims 1 to 8 carried on a support adjacent to one of the two electrically conductive layers, the said support being transparent or translucent if it is adjacent to a transparent or translucent electrically conductive outer layer.

10. An electroluminescent device according to any one of claims 1 to 9 in which the support is of card or a plastics material and carries a printed electrically conductive layer on which is printed successively the dielectric layer and the light generator layer.

11. A method for making an electroluminescent device as claimed in any of the preceding claims which comprises successively printing, on to an electrically conductive layer, layers of ink having dispersed therein, respectively either a finely divided solid of high dielectric constant or a finely divided solid phosphor, and applying to the second printed layer a second electrically conductive outer layer.

12. A method according to claim 11 in which at least one of the inks comprises a UV-curable binder and the said binder is cured by exposure to actinic radiation after the said ink has been printed.