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(71) Applicants:
- **Barton, Richard Peter James**
  **Ulverston**
  **LA12 7NQ (GB)**
- **May, William, Wallace**
  **Ulverston**
  **LA12 7NQ (GB)**

(72) Inventors:
- **Barton, Richard Peter James**
  **Ulverston**
  **LA12 7NQ (GB)**
- **May, William, Wallace**
  **Ulverston**
  **LA12 7NQ (GB)**

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Amended claims in accordance with Rule 137(2) EPC.

## (54) Dot matrix and segmented displays with uniform illumination

(57) This invention relates to white and coloured dot-matrix and segmented displays in which the colour is produced by means of blue or ultra-violet light-emitting diodes (LED) together with a wavelength conversion phosphor, or combination of phosphors. A white or coloured dot-matrix display is produced by conversion of blue or Ultra-Violet light from an array of light-emitting diodes (LEDs) **1** by means of a layer of phosphor **5** applied to a substrate **4** so as to provide uniform illumination over the areas **8**. In comparison to the previous art the invention improves the uniformity and consistency of illumination over the illuminated areas of the display and also improves reliability by distancing the phosphor layer **5** from the dissipation generated by the LEDs **1**.

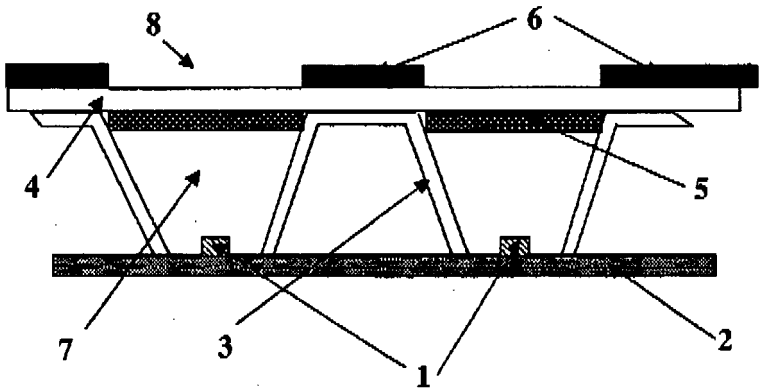


**Figure 1**

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## Description

### Technical Field

**[0001]** This invention relates to displays, and in particular to white and coloured dot-matrix and segmented displays in which the colour is produced by means of blue or ultra-violet light-emitting diodes (LED) together with a wavelength conversion phosphor, or combination of phosphors.

### Background Art

**[0002]** A typical manufacturing process for a dot-matrix or segmented display corresponding to the existing art is described here with reference to Figure 2. A single moulding **11** is produced with holes 12 at the position of each illuminable element in the display. Around each of these holes the moulding forms a reflector cup which serves to prevent light from leaking from one hole to adjacent holes. The surface of the moulding 11 is made opaque either by including suitable light absorbing substance in the material of the moulding or by coating the surface of the moulding with an opaque paint. LED chips 8 are mounted on a printed circuit board **9** carrying two sets of addressing contact lines, usually one on the top surface, and the second set on the lower surface. Where necessary, standard plated-through via holes allow electrical contact to be made between the lower addressing lines and the LEDs. To assemble the display the circuit board is placed in position using locating pegs so that one or more LEDs is contained inside each reflector cup, and the complete assembly is then filled with a clear epoxy **10** which may contain a diffusing material such as titania (titanium dioxide) particles. For a white display the epoxy may alternatively or additionally contain phosphor particles **13** which can be excited by the blue or UV LED array **8.** The epoxy serves to maintain the whole assembly rigidly together, to protect the printed circuit board, to improve light extraction from the LED chip, and to maintain in position the pins used for electrical connection between the LED chips and the addressing lines.

**[0003]** Within the last twenty year period, patents have been granted describing slightly modified methods of manufacture. For example, US Patent 4713579, granted 15/12/1987, describes a modified technique for assembling dot-matrix luminous displays. The patent claims that the previous practice was to use two boards, each of which carried one set of electrodes. LEDs were mounted in holes at the intersection of the electrodes, and the display was completed by an epoxy deposited over the complete surface and filling the holes containing the LEDs. The claimed disadvantage is that during fabrication, or under extremes of temperature, the board can distort as a result of differences in thermal expansion between the boards and the protective coating. The solution described in the patent is to mount the LEDs on a single board, with electrodes on the upper and lower faces, and define the display pattern by means of holes in a flexible sheet that is bonded to the board by means of epoxy only at the position of the LEDs. It is claimed that flexibility of the sheet prevents distortion.

**[0004]** A subsequent patent US 4914731 describes another simplified method of fabricating LED dot-matrix and segment displays. The display is formed from three injection moulded elements together with a circuit board on which the LEDs are mounted. The first injection moulded element is a lens, circular for a dot-matrix display or lozenge shaped for a segment display, the second is a screen which has holes defining the display pattern, and the third is the reflector cup to contain the LED and which has a reflecting coating on the inside. The three injection moulded elements are pushed together, and the circuit board glued to the back to form the complete display. It is claimed that this method reduces manufacturing costs, and eliminates the need to cover the inside of the cups holding the LEDs or the edges of the display with an opaque ink to prevent leakage of light.

**[0005]** These two patents are concerned exclusively with the use of single colour LEDs in displays, corresponding typically to red, green or amber displays. Although the methods of manufacture described above are relevant to white light displays, these earlier patents do not address the problems of the quality of the white light in the displays, the problem of degradation of the light output, or the way in which phosphors can be incorporated into displays. In particular, the quality of the light as described by the chromaticity co-ordinates, the colour temperature, or the colour rendering index, is a problem for white light lamps and displays both because the illumination can appear different in different parts of the display or when viewed at different angles, and also because the intensity and quality of the light can change with time. Degradation is a much more significant concern for blue and white coloured displays than it is for longer wavelength displays involving, for example, green, red or yellow LEDs.

**[0006]** European Patent Application EP1566848, filed by Lumileds Lighting (and based on a US Patent Application 20050184638) describes an extension of earlier LED patents concerning more than one phosphor incorporated into an LED in order to improve the quality of the white light. The invention is intended to overcome the stated problem of interaction between phosphors by including them in discrete layers or over separate areas. Dichroic filters are also included to transmit and reflect specified wavelengths in the illumination devices. The implied applications include illumination of a Liquid Crystal Display (LCD) but all the claims are concerned exclusively with ways in which different phosphors can be combined. No claims are included in the patent for dot matrix or segment displays.

**[0007]** European patent application publication number EP1667091 describes an LED display showing digital characters or patterns. Patent application EP1667091 claims that the use of a shaped cavity and

"an optically conductive ink" can give internal reflection effects which lead to a more uniform display pattern. The cavity containing the LEDs is narrower at the top than at the base and a screen diffuser is used in place of the diffusing epoxy. No phosphor is described in this patent.

**[0008]** US Patent Application US2005006659, entitled "Light emitting diode utilizing a discrete wavelength-converting layer for color conversion" describes the use of a "cap" above an LED to provide typically white light. An essential part of all claims in this publication describe "mounting a preformed transparent cap" over the LED chip. The various claims correspond in essence to different forms of cap, with the cap having different shapes and containing phosphor material in different forms ranging from a sheet of single crystal phosphor to a phosphor powder suspended in a clear compound. The fact that all claims include the word cap indicates that it is an essential part of the claim. According to the Collins English Dictionary, in this sense cap is defined as "something that protects or covers, especially a small lid or cover". This sense of a small cover is in accord with the sense in which it is used US2005006659, where the transparent cap is used to cover a single LED chip which invariably has a dimension less than 1mm by 1mm. The use of a cap covering a single LED chip is completely different to the use of a phosphor containing layer described in this application where the layer is applied to a complete display covering a large number of LED chips

**[0009]** Further, the background discussion in US2005006659 refers only to LEDs for lighting and the invention is intended as a candidate for replacement of incandescent and fluorescent lights, and not for use in a display. Together with the use of the cap to cover only a single LED, and no mention of displays in the application, it is clear that US2005006659 is referring to a completely different application of a LED-phosphor combination.

**[0010]** The phosphor-containing cap is taken to be a preformed three-dimensional discrete entity, either a single crystal or prepared by "transfer moulding, injection moulding or casting". In contrast, the specific embodiment of the phosphor layer described in this application is prepared by the essentially two-dimensional techniques of screen printing or similar method of thin film deposition.

**[0011]** A problem with previous dot-matrix and segmented displays and one not addressed in previous patents concerned with phosphor conversion displays is lack of uniformity of the illuminated area in the display. Segregation and agglomeration of the phosphor in the epoxy gives a non-uniform phosphor distribution that in turn gives a non-uniform appearance to the display and can allow the underlying LEDs to be observed as bright spots within the illuminated areas of the display. The invention described in the present patent uses a film or layer of phosphor or phosphor containing material to provide a uniform and consistent coating that produces uniform illumination.

**[0012]** The invention described in the present patent is a method of manufacture of white and other phosphor-conversion LED dot-matrix or segment displays that also avoids the degradation observed in earlier displays, and gives more uniform colour in the case of phopshor converted displays.

## Disclosure

**[0013]** The invention will initially be described by reference to one specific implementation of a white segmented display as shown in the figures.

Figure 1 shows a cross-section of one particular implementation of a seven-segment display

Figure 2 shows the previous art.

Figure 3 shows a) the phosphor pattern and b) the opaque pattern produced by the printing process.

**[0014]** The display is realised in the conventional way except for the way in which the phosphor material is incorporated. In Figure 1 the blue or UV LED chips **1** are attached to the printed circuit board **2** for example by soldering or epoxy die attach, and the display pattern is defined by moulding **3**.The additional innovative steps are now described below.

1. A suitable phosphor material is chosen to complement the blue LED die. For example, a standard Yttrium. Aluminium Garnet (YAG) phosphor activated with Cerium (Ce) can be used with a 470nm blue LED. This phosphor is incorporated with a suitable binding agent using where necessary appropriate surface treatment to produce a fluid suitable for silk-screen printing, doctor blading or other process for depositing thin films. The particle size distribution of the phosphor must be chosen to allow good incorporation with the binding agent and good resolution of the display.

2. A set of stencils is produced for the particular product under consideration. In some cases it may be sufficient to have a single uniform film of phosphor, but in general at least one screen will be needed for the illuminated areas, and one for the opaque areas. As an example, figures 3a) and 3b) show the patterns created by the two stencils needed for a segmented display.

3. A suitable high-transmission material is selected to form the substrate **4**. Correct selection of this material is essential in order to ensure good adhesion of the phosphor-containing inks, Ultra-Violet resistance, and flexibility after the printing process.

4. The phosphor-containing ink 5 is printed on to the substrate in a pattern to suit the product. The thick-

ness of the printed phosphor is chosen to give the desired chromaticity co-ordinates and will normally be in the range 5 to 100 microns. The resulting pattern of the phosphor film printed on the reverse side of the substrate is shown in Figure 3a). If necessary an opaque ink **6** is also printed onto the substrate. Figure 3b) shows a pattern of opaque ink printed on the upper surface of the substrate to be combined with the phosphor pattern shown in Figure 3a).

5. The moulding **3** together with the printed circuit board **2** and the substrate **4** are than assembled and held in place by a clear epoxy 7 or other suitable materials such as silicone.

6. If required the exposed surface of the substrate can be overprinted with a suitable varnish or other protective coating.

**[0015]** It is understood that the embodiment described in figures 1 and 3 is only one of a number of different embodiments, and is described by way of example only. The display can be any segmented or dot matrix display or any other displays that require illuminated and dark regions. Other ways of holding the LED lamps in position can also be used and different phosphors can be used to produce light with different chromaticity co-ordinates. Examples include in particular the use of phosphors that emit green light in order to overcome the well-known problem of low efficiency for LEDs emitting in the green region of the spectrum. Other methods of depositing the phosphors on the substrate can also be used in addition to those described above, and a range of materials can be used as the substrate.

**[0016]** A major advantage of the method described in step 4) is the ability to control the thickness of the phosphor, and hence to control the quality and consistency of the light emitted from the display. In contrast, the earlier approach where the phosphor was incorporated in the epoxy **10** in Figure 2 gives rise to problems of settlement and aggregation that makes it difficult to control the amount of phosphor emission and to control the uniformity of the emission in different directions. The thickness of the phosphor layer will depend on the phosphor being used, but is typically in the range 5 to 100 microns. More than one layer can be applied successively in order to improve the uniformity and to control the thickness. The distribution of particle sizes in the phosphor is not critical, but for effective screen printing the maximum diameter of the phosphor particles should typically be below 20 microns. Phosphor particles can both scatter the blue light, where the direction of propagation is changed but the wavelength is unchanged, and convert blue light to light of a longer wavelength. The presence of small phosphor particles with diameter less than a few microns, or larger phosphor particles with small crystallite sizes, improves the angular uniformity of light quality by providing this scattering of blue light.

## Claims

1. A segmented or dot-matrix display in which a white or coloured display is produced by conversion of light from light-emitting diodes (LEDs) mounted behind a perforated screen that defines the elements in the display pattern, the colour conversion produced by means of one or more phosphors which partially or totally convert the light from the LED to light of different wavelengths, and where the resulting light seen in the illuminated regions of the display is the result of a combination of the light emitted by the LEDs and the light emitted by the phosphors,
**characterized by** phosphors applied in the form of a uniform layer, which can be built up from multiple thinner layers, supported by a transparent substrate attached to the perforated screen so as to provide uniform illumination from the illuminated areas of the display and to distance the phosphor layer from the dissipation generated by the LEDs.

2. A display according to claim 1 **characterised by** an additional opaque layer applied to the substrate over the non-illuminable areas of the display to prevent the leakage of light from one illuminated area to another.

3. A display according to claim 1 **characterised by** a phosphor layer produced by screen printing using an ink suitable for screen printing containing phosphor, binder and solvent.

4. A display according to claims 1 **characterised by** a blue LED and a phosphor chosen to completely absorb and convert the blue light from the LED to produce a display that emits green illumination.

5. A display according to claims 1 **characterised by** an LED emitting in the ultra-violet region of the spectrum and a phosphor or combination of phosphors chosen to produce white light.

6. A display according to claims 1 **characterised by** the use of different phosphors for different parts of the substrate so as to produce a display that provides light of different colours in different illuminated regions of the display.

**Amended claims in accordance with Rule 137(2) EPC.**

**1.** A segmented or dot-matrix display in which a white display is produced by conversion of light from light-emitting diodes (1) mounted in a moulding (3) that defines the elements in the display pattern such that one or more light-emitting diodes are mounted behind each aperture in the moulding, the colour con-

version produced by means of one or more phosphors which partially convert the light from the LED to light with a distribution of different wavelengths, and where the resulting light seen in the illuminated regions of the display is the result of a combination of the light emitted by the LEDs and the light emitted by the phosphors,
**characterized by** phosphors applied in the form of particles contained in a transparent binder to produce a uniform layer of defined thickness with the thickness chosen to give the desired colour temperature of white light and the uniform phosphor layer supported by a transparent substrate (4) attached to the moulding.

**2.** A display according to claim 1 **characterised by** a phosphor layer produced by screen printing using an ink suitable for screen printing containing phosphor, binder and solvent.

**3.** A display according to claim 1 **characterised by** an additional opaque layerapplied to the substrate over the non-illuminable areas of the display to prevent the leakage of light from one illuminated area to another.

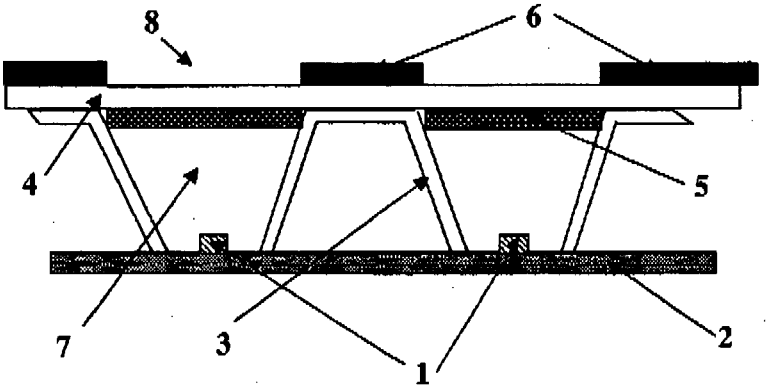
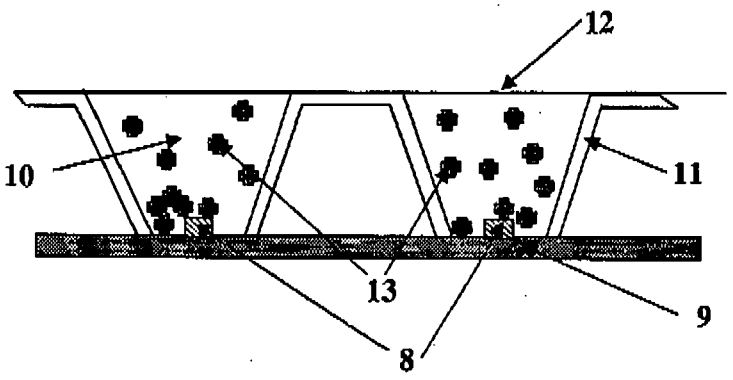
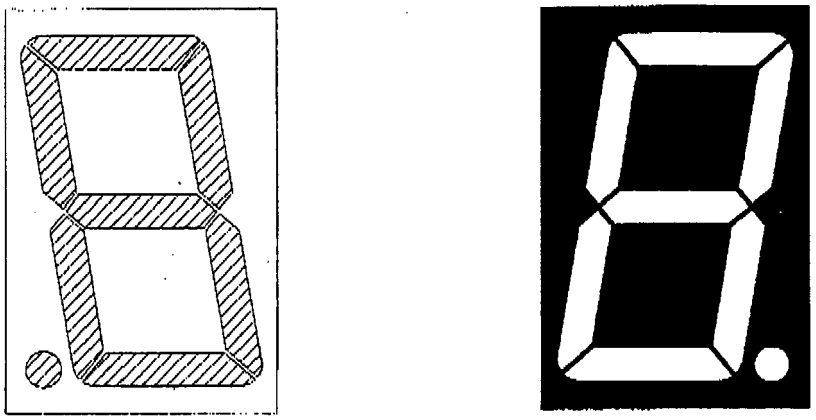



Figure 1




Previous state-of-the-art

Figure 2



a) b)

Figure 3

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# EUROPEAN SEARCH REPORT

Application Number
EP 08 01 7601

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 12 March 2009 | Pavlov, Valeri |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 01 7601

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## REFERENCES CITED IN THE DESCRIPTION

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