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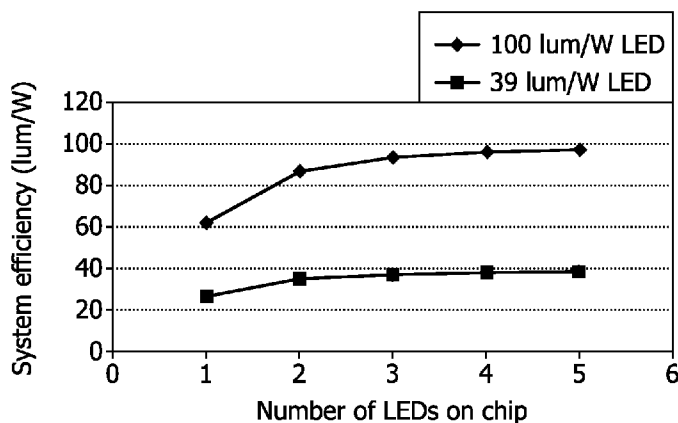


FIG. 4

(57) Abstract: A light output device comprises an at least partly light transmissive substrate arrangement (1, 2) with a plurality of light source arrangements (4) integrated into the structure of the substrate arrangement. At least one of the light source arrangements comprises a casing comprising exactly 2, 3 or 4 discrete semiconductor LED chips. The invention thus provides an embedded multi-chip package/casing in a transparent substrate arrangement. The small number of LEDs per casing gives two possible advantages; one is that a colour output is made possible and the other is that it enables an improvement in efficiency to be obtained but without excessive increase in cost.

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Light output device

FIELD OF THE INVENTION

This invention relates to light output devices, in particular using discrete light sources associated with a light transmissive substrate structure.

5 BACKGROUND OF THE INVENTION

One known example of this type of lighting device is a so-called "LED in glass" device. An example is shown in Figure 1. Typically a glass plate is used, with a transparent conductive coating, for example ITO, forming electrodes. The conductive coating is patterned in order to make the electrodes, that are connected to a semiconductor LED
10 device. The assembly is completed by laminating the glass, with the LEDs inside a thermoplastic layer (for example polyvinyl butyral, PVB). The glass used may be safety glass. Applications of this type of device are shelves, showcases, facades, office partitions, wall cladding, and decorative lighting. The lighting device can be used for illumination of other objects, for display of an image, or simply for decorative purposes.

15 A first problem with type of device is how to reduce the power loss in the ITO conductor arrangement.

A second problem is how to dynamically control the color output of LEDs in glass. Individual red, green and blue LEDs can be provided but these can be seen individually by the viewer, so that the desired colour output is not perceived.

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SUMMARY OF THE INVENTION

According to the invention, there is provided a light output device comprising an at least partly light transmissive substrate arrangement with a plurality of light source arrangements integrated into the structure of the substrate arrangement,

25 wherein at least one of the light source arrangements comprises a casing comprising exactly 2, 3 or 4 discrete semiconductor LED chips.

The invention thus provides an embedded multi-chip package/casing in the transparent substrate arrangement. The small number of LED chips per casing gives two possible advantages; one is that a colour output is made possible and the other is that it

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enables an improvement in efficiency to be obtained but without excessive increase in cost. These different advantages are for different implementations of the invention, which will be described further below.

5 The chips are preferably in close proximity, for example spaced by less than 0.1 mm so that they can be used to generate a colour output without the individual constituent colours being perceivable. Alternatively, the connections between the individual chips can give improved efficiency by reducing the current flow for a given combined light output.

10 The total light output from the LEDs of the casing is preferably less than 10 lumen, so that the casing and especially the surrounding transparent substrate structure can withstand the total power usage (for example, for long-term performance PVB may not be heated above a certain temperature, for example 80 °C).

In one example, the LEDs are connected in series, and this gives the desired reduction in current to achieve a given light output from the particular type of LED device. The LEDs of the casing can be identical, for example white light sources.

15 In another arrangement, the LEDs of the casing can comprise different colour LEDs, and they are then connected in parallel, to be independently controllable. This enables a colour output to be provided without the viewer being able to see the individual LEDs.

The substrate arrangement can comprise first and second transparent substrates and an electrode arrangement embedded in the substrate arrangement, with the plurality of
20 light source arrangements connected to the electrode arrangement.

The plurality of light source arrangements can be embedded in a thermoplastic layer.

In an embodiment at least some of the light source arrangements comprise a casing comprising exactly 2, 3 or 4 discrete semiconductor LED chips.

25 In another embodiment all of the light source arrangements comprise a casing comprising exactly 2, 3 or 4 discrete semiconductor LED chips.

It is noted that the invention relates to all possible combinations of features recited in the claims.

30 BRIEF DESCRIPTION OF THE DRAWINGS

Examples of the invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 shows a known LED in glass illumination device; and

Figure 2 shows a single LED of the device of Figure 1 in more detail;

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Figure 3 shows an equivalent circuit of an LED device connected to a conductor arrangement; and

Figure 4 is used to explain the advantage of the invention.

The same reference numbers are used to denote similar parts in the different
5 figures.

DETAILED DESCRIPTION

The structure of an LED in glass illumination device is shown in Figure 2. The lighting device comprises glass plates 1 and 2. Between the glass plates are (semi-) transparent electrodes 7a and 7b (for example formed using ITO), and a LED 4 connected to
10 the transparent electrodes 7a and 7b. A layer of thermoplastic material 5 is provided between glass plates 1 and 2 (for example PVB or UV resin).

The glass plates typically may have a thickness of 1.1mm - 2.1 mm. The spacing between the electrodes connecting to the LED is typically 0.01 – 3 mm, for example
15 around 0.15 mm. The thermoplastic layer has a typical thickness of 0.3mm- 2mm, and the electrical resistance of the electrodes is in the range 2 - 80 Ohm, or 10-30 Ohms/square. The LEDs are typically spaced by approximately 3cm or more.

The electrodes are preferably substantially transparent, so that they are imperceptible to a viewer in normal use of the device. If the conductor arrangement does not
20 introduce a variation in light transmission (for example because it is not patterned, or because the pattern cannot be seen), a transparency of greater than or equal to 50% may be sufficient for the system to be transparent. More preferably, the transparency is greater than 70%, more preferably 90%, and even more preferably 99%. If the conductor arrangement is patterned (for example because thin wires are used), the transparency is preferably greater than 80%,
25 more preferably 90%, but most preferably greater than 99%.

The electrodes can be made of a transparent material such as ITO or they can be made of an opaque material such as copper but be sufficiently thin so that they are not visible in normal use. Examples of suitable materials are disclosed in US 5 218 351.

In accordance with the invention, the LED 4 comprises a multi-chip LED
30 package or casing 4 connected by the transparent electrodes 7a and 7b. The multi-chip LED casing contains 2, 3, or 4 LED chips. The total lumen output is preferably less than 10 lumens.

LED packages/casings are known in the art. A multi-chip package is also known as multi-dye package. Typically it comprises a ceramic or resin package/board,

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comprising a plurality of LED chips connected to a conductor arrangement. In the device of the invention, the conductor arrangement of such a device has leads or electrodes which are connected to the ITO conductor arrangement arranged on one of the substrates.

The plurality of 2, 3 or 4 chips are thus mounted on a common circuit board
 5 with electrical connections to leads, which leads are subsequently connected to the transparent (e.g. ITO) conductor arrangement. The complete device comprises a plurality of these common boards, embedded in the glass substrate structure.

An example of available multiple LED chip device is manufactured by
 OSTAR (Trade Mark), under the product name LE W E2A. This product has 4 LED chips
 10 connected in series. The LED casing typically operates at a voltage of around 15V.

These devices include a metal core board, and this would not be required for this application, where the casing is to be incorporated into a glass laminate structure.

In a first embodiment, the LED chips are connected in series inside the LED casing. This increases the total voltage over the casing. However, the current flowing
 15 through the system is adapted in order to keep the lumen output of the LED casing the same as for the single LED chip. Thus, the current (which is essentially proportional to the light output intensity of the LED) can be reduced by a factor n where n is the number of series connected LED chips.

A simple electrical model can be used to describe the LED connected to the
 20 transparent conductor arrangement, as shown in Figure 3. The model comprises ITO resistances 30 and a LED 4, and the system is driven by a fixed current.

In order to calculate the power usage in this system, the following equations may be used:

$$\begin{aligned} P_{ITO} &= I^2 R_{ITO} \\ P_{LED} &= V_{LED} I \\ P_{Total} &= P_{ITO} + P_{LED} \end{aligned}$$

From these equations, it can be seen that the power loss in the ITO conductor scales with the square of the current, while the power use in the LED scales linearly with current. Thus, if the current is reduced, an improvement in system efficiency can be achieved.

30 For example, if a casing with 2 LED chips is used, the current flowing through the LEDs may be reduced to 50% to keep the total LED power the same.

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Figure 4 shows a calculation of system efficiency using two types of LEDs (39 and 100 lum/Watt) as a function of number of LED chips per casing, in series inside the casing. It can be seen that the efficiency improvement is very high for the first increase in number of LED chips. When using 1 chip with 100 lum/Watt output, the system efficiency is around 60-70% and when using 4 chips the system efficiency is greater than 96%.

A further increase in number of LED chips (beyond 4) is no longer advantageous, because it would only barely increase the system efficiency, but at the same time it makes the system more expensive, and less transparent due to the increasing casing size.

Thus, the invention provides a system in which there are 2,3, or 4 LED chips mounted within a common casing or on a common board. Due to heating effects, it is not possible to increase the power per casing to any desired value. For example, for LEDs with current state-of-the-art 39 lum/Watt white LEDs, the maximum power is around 0.23 Watt, giving a light output of 8.7 lumen.

Thus, the total lumen output is preferably lower than 10 lumen.

The embodiments above have been described with the aim of increasing efficiency, by reducing ITO electrical losses within an LED casing.

An alternative use of a multi-chip casing of the invention is to provide LED chips with a different output color, such as RGB, or RGBA (red green blue alpha). Because the LED chips are arranged in a single casing, a viewer is unable to distinguish the individual LEDs by eye. Also, three or four different colors is sufficient to be able to generate all possible colors in the visible spectrum.

For controlling the RGB or RGBA LEDs it is required to adapt the pattern of the conductor arrangement 7. For example, six ITO electrodes per LED can be used in order to individually control red, green and blue. Alternatively four ITO electrodes per LED may be used, by connecting each color to one dedicated ITO source electrode and one common ITO drain electrode for all colors.

By varying the current through the individual LED chips it is possible to tune the output of the system to any desired output color. Of course, this requires the LED chips to be in parallel.

If multi-color LED chips are connected in series, they will generate white light only, but with an improvement of system efficiency as explained above compared to parallel connected LED chips.

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The use of a multi-chip casing gives improved system efficiency. As the efficiency of the individual LED chips improves with development over time (i.e. improved light output per unit current), the multi-chip casing can provide further reduction in ITO losses. The number of LEDs in each chip will be selected to provide the required

5 compromise between system efficiency (more LEDs give lower currents and reduced losses) and cost (more LEDs per casing give increased cost).

As shown in Figure 1, the LED casings are preferably spaced across the device, preferably with spacing more than 1cm, and typically with spacing of around 3cm.

A small number of possible materials to form the transparent (or at least semi-

10 transparent) electrodes have been outlined above. Other include electrically conductive wires, strands made of a resin such as polyester or nylon wires the outer surface of which is coated with metal by vapour deposition, metal plating or the like. Conductive films of vapour-deposited SiO₂-indium alloy can also be used. A conductive ink can also be used.

Various modifications will be apparent to those skilled in the art.

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CLAIMS:

1. A light output device comprising an at least partly light transmissive substrate arrangement (1, 2) with a plurality of light source arrangements (4) integrated into the structure of the substrate arrangement,
wherein at least one of the light source arrangements comprises a casing
5 comprising exactly 2, 3 or 4 discrete semiconductor LED chips.
2. A device as claimed in claim 1, wherein the discrete semiconductor LEDs are spaced by less than 0.1 mm.
- 10 3. A device as claimed in claim 1 or 2, wherein the light source arrangements are spaced by at least 1cm.
4. A device as claimed in any preceding claim, wherein the total light output from the LEDs of the casing is less than 10 lumen.
- 15 5. A device as claimed in any preceding claim, wherein the LEDs are connected in series.
6. A device as claimed in claim 5, wherein the LEDs in the casing are identical.
- 20 7. A device as claimed in any one of claims 1 to 5, wherein the LEDs of the casing comprise different colour LEDs.
8. A device as claimed in any one of claims 1 to 4, wherein the LEDs of the casing comprise different colour LEDs and LEDs in each casing are connected in parallel to
25 be independently controllable.
9. A device as claimed in any preceding claim, wherein the substrate arrangement comprises first (1) and second (2) transparent substrates and an electrode

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arrangement embedded in the substrate arrangement, with the plurality of light source arrangements connected to the electrode arrangement.

10. A device as claimed in any preceding claim, wherein the plurality of light
5 source arrangements are embedded in a thermoplastic layer.
11. A device as claimed in any preceding claim, wherein the electrode
arrangement comprises an at least semi-transparent conductor arrangement.
- 10 12. A device as claimed in claim 11, wherein the conductor arrangement is formed
of a fully transparent material.
13. A device as claimed in claim 12, wherein the conductor arrangement is formed
of a transparent conductive oxide.
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14. A device as claimed in claim 13, wherein the conductor arrangement is formed
of ITO.
15. A device as claimed in any preceding claim, wherein each casing comprises
20 exactly 2 semiconductor chips.
16. A device as claimed in any one of claims 1 to 14, wherein each casing
comprises exactly 3 semiconductor chips.
- 25 17. A device as claimed in any one of claims 1 to 14, wherein each casing
comprises exactly 4 semiconductor chips.

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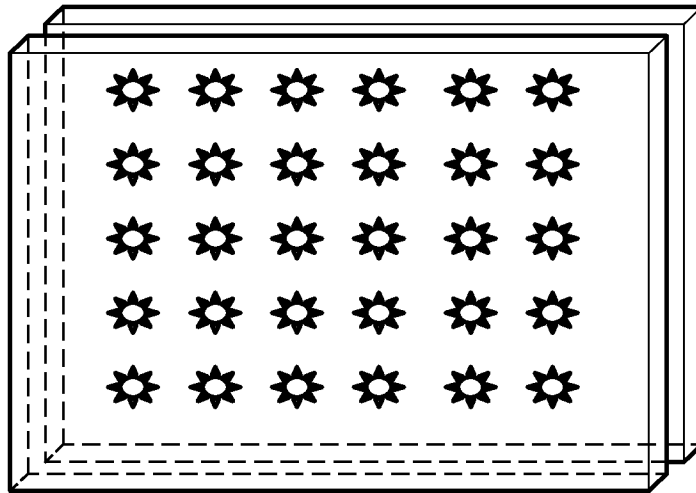


FIG. 1

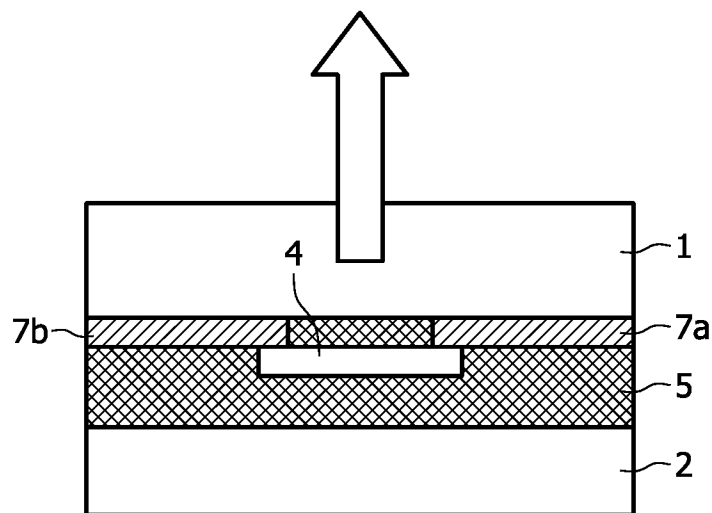


FIG. 2

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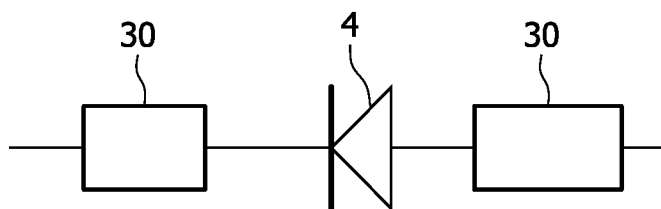


FIG. 3

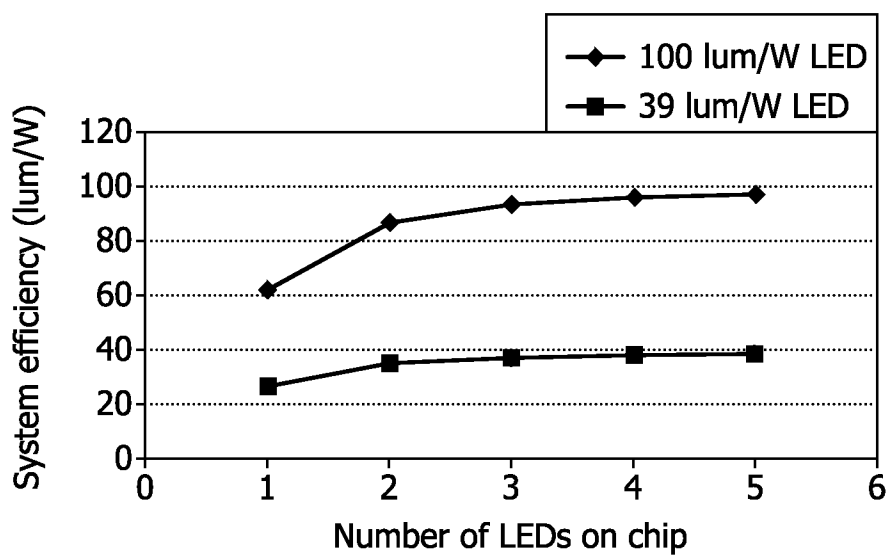


FIG. 4