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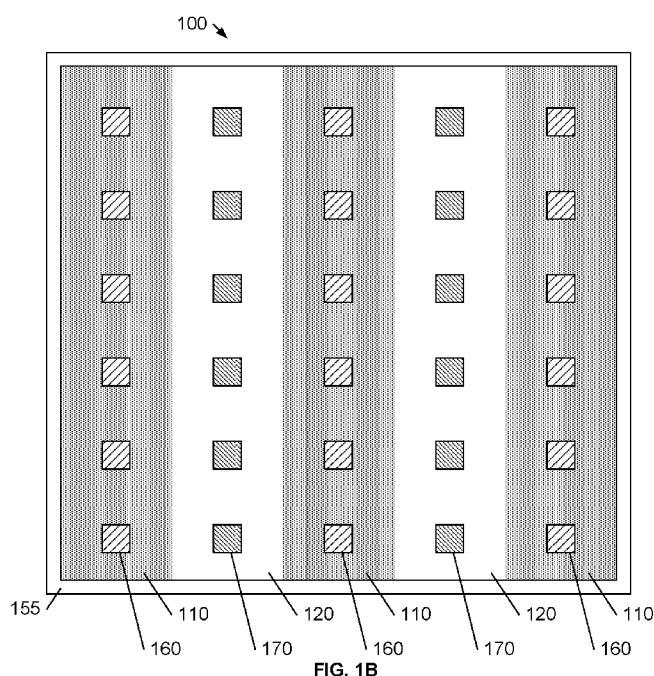
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(54) Title: HYBRID CHIP-ON-BOARD LED MODULE WITH PATTERNED ENCAPSULATION



(57) Abstract: Different wavelength conversion materials, or different concentrations of a wavelength conversion material are used to encapsulate the light emitting elements of different colors of a hybrid light emitting module. In an embodiment of this invention, second light emitting elements (170) of a particular color are encapsulated with a transparent second encapsulant (120;420;520), while first light emitting elements (160) of a different color are encapsulated with a wavelength conversion first encapsulant (110;410;510). In another embodiment of this invention, a particular second set of second and third light emitting elements (170,580) of different colors is encapsulated with a different encapsulant than another first set of first light emitting elements (160).



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— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) — with international search report (Art. 21(3))

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HYBRID CHIP-ON-BOARD LED MODULE WITH PATTERNED ENCAPSULATION

This invention was made with U.S. Government support under Contract No. DE-EE0005099 awarded by the Department of Energy (DOE). The Government has certain rights in this invention.

FIELD OF THE INVENTION

This invention relates to the field of light emitting elements, and in particular to a hybrid (multiple light emitting elements of different colors) LED module that includes a patterned encapsulation that provides different wavelength conversion elements for different colors.

BACKGROUND OF THE INVENTION

With the increased demand for high-output semiconductor light emitting devices (LEDs), modules comprising an array of light emitting elements are often used. The individual light emitting elements may be "mid-power", consuming less than a half watt, and dozens may be contained in the array, providing relatively high light output intensity.

To produce a desired color, such as white light, light of different wavelengths are combined. In some embodiments, the array of light emitting elements may include sets of light emitting elements of different color, such as red, blue, and green/yellow. The intensity of the light output of each color will define the color of the composite light output from the array.

In other embodiments, the array of light emitting elements may all emit light of the same wavelength, and wavelength conversion material may be used to convert at least a portion of the light emitted by the light emitting elements to different wavelengths, such that the light output is a combination of the originally emitted light and the wavelength converted light. This wavelength conversion material is commonly contained in the encapsulant that covers the array.

"Chip-on-Board" (COB) is an array architecture that is commonly used because of its flexibility and low cost. A COB may comprise an array of light emitting elements arranged on a substrate and covered by an encapsulant within a ring or dam surrounding the light emitting elements. The encapsulant may be a silicone compound that is poured into the dam

5 then cured, or it may be a preformed element, such as a silicone sheet or a ceramic that is contained within the ring. Commonly, the encapsulant includes a wavelength conversion material that converts the light emitted by the light emitting elements to one or more other wavelength.

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SUMMARY OF THE INVENTION

It would be advantageous to provide a hybrid light emitting module in a chip-on-board architecture that is more efficient than conventional chip-on-board modules.

To better address one or more of these concerns, in an embodiment of this invention,

15 different wavelength conversion materials, or different concentrations of a wavelength conversion material may be used to encapsulate the light emitting elements of different colors. In an embodiment of this invention, the light emitting elements of a particular color are encapsulated with a transparent encapsulant, while the light emitting elements of a different color are encapsulated with a wavelength conversion encapsulant. In another

20 embodiment of this invention, a particular set of light emitting elements of different colors is encapsulated with a different encapsulant than another set of light emitting elements.

The applicants have recognized that although each phosphor may efficiently absorb light of a first range of wavelengths and emit light of a desired second range of wavelengths, the phosphor may also absorb light of other wavelengths and not emit light at all, or emit a

25 minimal amount of light at a third, perhaps undesired, range of wavelengths, resulting in a loss of the absorbed light, and a corresponding loss of light output efficiency.

Accordingly, in embodiments of this invention, the light emitting elements of different colors are paired with encapsulants that efficiently produce a desired light output with minimal efficiency-reducing absorptions. The light emitting elements of light of a

30 particular wavelength that is not intended to be converted by the wavelength conversion material, for example, may be encapsulated with a phosphor-free encapsulant, while light emitting elements of light that is intended to be converted may be encapsulated with a phosphor, or phosphor mix, that efficiently converts some or all of the light to a desired wavelength or set of wavelengths.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in further detail, and by way of example, with reference to the accompanying drawings wherein:

5 FIGs. 1A-1B illustrate an example light emitting module that includes different encapsulant material situated over sets of light emitting elements of different colors.

FIG. 2 illustrates an example controller for adjusting the relative intensity of the light output from each set of light emitting elements.

10 FIG. 3 illustrates an example of another light emitting module that includes different encapsulant material situated over sets of light emitting elements of different colors.

FIG. 4 illustrates an example of a light emitting module that includes differently shaped encapsulant material situated over sets of light emitting elements of different colors.

FIG. 5 illustrates an example of a light emitting module that includes different encapsulant material situated over different sets of light emitting elements.

15 Throughout the drawings, the same reference numerals indicate similar or corresponding features or functions. The drawings are included for illustrative purposes and are not intended to limit the scope of the invention.

DETAILED DESCRIPTION

20 In the following description, for purposes of explanation rather than limitation, specific details are set forth such as the particular architecture, interfaces, techniques, etc., in order to provide a thorough understanding of the concepts of the invention. However, it will be apparent to those skilled in the art that the present invention may be practiced in other embodiments, which depart from these specific details. In like manner, the text of this
25 description is directed to the example embodiments as illustrated in the Figures, and is not intended to limit the claimed invention beyond the limits expressly included in the claims. For purposes of simplicity and clarity, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

FIG. 1A illustrates a profile view and FIG. 1B illustrates a top view of an example light emitting module 100 that includes different encapsulant material situated over sets of light emitting elements of different colors. For ease of reference and understanding, the terms 'encapsulant' and 'encapsulate' are used herein in a general sense to include a material that 5 covers the light emitting surface of the light emitting elements, to receive substantially all of the light emitted from the light emitting surface or light emitting surfaces.

In FIGs 1A-1B, light emitting elements 160 emit a different color light than the light emitting elements 170. The light emitting elements 160, 170 are illustrated as being situated on a substrate, or board 150 that includes conductive elements (not illustrated) that serve to 10 provide external power to the light emitting elements 160, 170. The light emitting elements 160, 170 may be discrete light emitting devices that are soldered to the conductive elements ('chip-on-board'), or may be elements that are situated on an intermediate substrate that is coupled to the conductive elements on the board 150. One of skill in the art will recognize that other configurations of light emitting elements on a substrate may be used.

15 A first encapsulant 110 is used to cover the light emitting elements 160, and another encapsulant 120 is used to cover the light emitting elements 170, each of the encapsulants 110, 120 having different wavelength conversion attributes. Optionally, walls 155 on the board 150 facilitate handling of the module 100, and may serve to contain the encapsulants 110, 120.

20 The bands of encapsulant 110, 120 may be formed by situating a thin barrier between each of the bands, then filling the regions between the barriers with the appropriate encapsulant 110, 120, typically in a semi-liquid form, such as a silicone compound, then hardening the encapsulant. The barriers may be removed as the encapsulant cures, or left within the module 100. If left within, the barriers may be transparent or reflective, depending 25 upon the desired light output pattern.

In an alternative embodiment, a pre-formed sheet may be provided that contains the bands of encapsulants 110, 120. The pre-formed sheet may be a partially cured silicone sheet patterned with the encapsulants 110, 120 using the aforementioned barriers. The partially cured silicone sheet is placed atop the light emitting elements 160, 170, then laminated to the board 150, as detailed in U.S. Patent 7,344,952, "Laminating Encapsulant Film Containing Phosphor Over LEDs", issued 3 July 2008 to Haryanto Chandra, and incorporated by reference herein. In the alternative, preformed sheets of encapsulant 110 be laminated over light emitting elements 160 and preformed sheets or liquids 120 may be used to cover light emitting elements 170 after the first lamination. In another alternative, the operations and materials may be reversed.

In an example embodiment, the light emitting elements 160 emit blue light, and the light emitting elements 170 emit red light. In such an embodiment, some of the blue light is intended to be converted to yellow/green light, whereas the red light is intended to be emitted directly. Accordingly, in this example embodiment, the encapsulant 110 may include phosphors that convert blue light to yellow/green light, and the encapsulant 120 may be phosphor-free.

In other embodiments, the light emitting elements 160 provide light of a first wavelength, light emitting elements 170 provide light of a second wavelength, and encapsulants 110, 120 provide corresponding light of third and fourth wavelengths.

Although light emitting elements of only two different colors are illustrated in this example, one of skill in the art will recognize that light emitting elements of a variety of different colors/wavelengths may be included in the light emitting module, with a variety of different encapsulants.

Likewise, patterns that are not banded, such as checkerboard patterns or unequal distribution of different types of light emitting elements and corresponding encapsulants, are contemplated and are included within the scope of the invention. In another alternative three or more pairs of light emitting elements /encapsulants are contemplated and are included within the scope of the invention.

FIG. 2 illustrates an example controller for adjusting the relative intensity of the light output from each set of light emitting elements. A controller 250 is provided with a source of power, and distributes this power to the sets of light emitting elements 160, 170 so as to provide a desired ratio of light output between the two sets. Although a series arrangement is 5 illustrated for each set of light emitting elements 160, 170, one of skill in the art will recognize that alternative arrangements, such as parallel and series-parallel, may be used to configure each set. In the alternative three or more types of light emitting elements are contemplated and are included within the scope of the invention.

In an example embodiment, the controller 250 may include controls that enable a user 10 to adjust the overall light output intensity as well as the ratio of light output provided by the combination of light emitting elements 160 and encapsulant 110 and the combination of light emitting elements 170 and encapsulant 120.

Although the encapsulants 110, 120 are illustrated in FIGs. 1A-1B with uniform 15 profile and clearly defined boundaries/edges, one of skill in the art will recognize that alternative configurations may be used, and that different combinations may be used to distribute light in the center different from light at the edges. For example, the spacing between and among the light emitting elements may vary to achieve a desired light output distribution, to accommodate light emitting elements having different light output intensities, 20 and so on.

One of skill in the art will also recognize that the different encapsulants 110, 120, may exhibit different light output patterns, due, for example, to different light scattering properties of the encapsulants 110, 120, or other optical effects. If desired, scattering agents or other materials may be added to one or both of the encapsulants 110, 120 to produce a desired 25 combination of effects, such as providing for similar scattering effects from each of the encapsulants 110, 120. In like manner, as detailed further below, the geometric shape of the encapsulants 110, 120 may differ to achieve a desired effect.

FIG. 3 illustrates an example of another light emitting module that includes different 30 encapsulant material situated over sets of light emitting elements of different colors. In this embodiment, the concentration of wavelength conversion elements (e.g. phosphors) within the encapsulant is varied such that a larger concentration 310 of phosphor is situated above the light emitting elements 160 and a substantially smaller concentration 320 of phosphor is situated above the light emitting elements 170.

The varying phosphor concentrations may be provided, for example, by applying a semi-liquid material, such as silicone, over the light emitting elements, then applying the phosphor material in selected regions, using, for example, screen printing or other patterning techniques. Alternatively, a multi-nozzle dispenser may dispense rows of different 5 encapsulants in semi-liquid form over the rows of light emitting elements, allowing for the fact that some blending of the different encapsulants may occur at the interface between each row.

FIG. 4 illustrates an example of a light emitting module that includes differently 10 shaped encapsulant material situated over sets of light emitting elements of different colors.

In the example embodiment of FIG. 4, the light emitting elements 170 are initially encapsulated in a hemispherical shape encapsulant 420, using, for example, silicone that is molded upon the light emitting elements 170. The hemispherical shape of the encapsulant 420 increases the range of the light output pattern from the encapsulant 420, particularly if 15 the encapsulant 420 does not contain a phosphor and the light emitting elements 170 emit directly without wavelength conversion.

Subsequent to the creation of the shaped encapsulant 420, a second encapsulant 410, such as a phosphor-containing silicone, may be applied to fill the regions between the domes 420.

20 One of skill in the art will recognize that the particular sequence of creating the encapsulants 410, 420 may be reversed, and the particular profile shape of the each encapsulant may vary, depending upon the desired light output pattern.

Although this invention has been presented using the paradigm of a two-color hybrid 25 module, with each color being exclusively encapsulated by the same encapsulant, one of skill in the art will recognize that different encapsulants may be applied to different mixtures, or sets of colors.

FIG. 5 illustrates an example of a light emitting module that includes different encapsulant material situated over different sets of light emitting elements.

30 As noted above, conventionally, the ratio of emitted light to converted light is controlled by the concentration of wavelength conversion elements in the wavelength conversion material. In an embodiment of this invention, the ratio of light of a first color to light of a converted color may also be controlled by providing a different encapsulant for a portion of the light emitting elements that emit the first color.

In the example of FIG. 5, some light emitting elements 580 are included within the set of light emitting elements 170 that are encapsulated in the encapsulant 520. These light emitting elements 580 may emit light at the same wavelength as the light emitting elements 160, or light of a different wavelength than either light emitting elements 160 or light emitting elements 170.

5 In an embodiment where the light emitting elements 580 are light emitting elements 160, the combination of light emitting elements 580 (also called 160) within the encapsulant 520 and the combination of light emitting elements 160 within the encapsulant 510 provide different light outputs.

10 The light emitting elements 580 that are within the encapsulant 520 with the light emitting elements 170 may be commonly controlled with the light emitting elements 170, or separately controlled. For example, if the light emitting elements 170 are red-emitting and the light emitting elements 580 are blue-emitting elements 160, and the encapsulant 510 is blue-to-yellow/green converting and the encapsulant 520 is transparent, a separate control of the 15 light emitting elements 580 (160) beneath the transparent encapsulant 520 will provide for an a measure of independent control of the blue content in the composite light output.

Alternatively, a common control of the light emitting elements 580 (160), 170 beneath the transparent encapsulant will provide for control of the ratio of red-blue light to blue/yellow/green light.

20

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. For example, it is possible to operate the invention in an embodiment wherein all of the light 25 emitting elements of a particular color are commonly controlled, independent of the encapsulant covering the light emitting element. In an alternative each light emitting element may be separately controlled.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A lighting module comprising:

5 a first plurality of light emitting elements of a first color,

a second plurality of light emitting elements of a second color,

10 a substrate upon which the first and second pluralities of light emitting elements are arranged, and

15 an encapsulation layer that includes a first encapsulant and a second encapsulant, the first encapsulant being positioned above each of the light emitting elements of the first plurality, and the second encapsulant being positioned over the light emitting elements of the second plurality,

wherein the first encapsulant includes a concentration of wavelength conversion material that is substantially greater than a concentration of wavelength conversion material in the second encapsulant.

15

2. The lighting module of claim 1, including a third plurality of light emitting elements of the first color, wherein the second encapsulant is positioned above each of the light emitting elements of the third plurality.

20

3. The lighting module of claim 1, wherein the concentration of wavelength conversion material in the second encapsulant is substantially zero.

25 4. The lighting module of claim 1, wherein the second encapsulant includes a scattering agent that is not included in the first encapsulant.

5. The lighting module of claim 4, wherein scattering properties of the scattering agent are substantially similar to scattering properties of the wavelength conversion material in the first encapsulant.

30

6. The lighting module of claim 1, wherein the second encapsulant is shaped to enhance light extraction from the second encapsulant.

7. The lighting module of claim 1, wherein a profile shape of the first encapsulant differs from a profile of the second encapsulant.

5 8. The lighting module of claim 1, wherein the light emitting elements of the first color emit blue light and the light emitting elements of the second color emit red light.

9. The lighting module of claim 1, wherein the first and second pluralities of light emitting elements are arranged in an alternating pattern on the substrate.

10

10. The lighting module of claim 1, including a controller that provides a first current to the first plurality of light emitting elements and a second current to the second plurality of light emitting elements, such that the respective levels of first and second currents determine a color point of light emitted from the lighting module.

15

11. The lighting module of claim 1, wherein at least one of the first plurality of light emitting elements and the second plurality of light emitting elements are mid-power LEDs.

20 12. The lighting module of claim 1, wherein the first encapsulant and the second encapsulant are contained in an enclosure that is situated on the substrate.

13. The lighting module of claim 1, wherein a spacing of the light emitting elements of the first and second plurality of light emitting elements on the substrate is non-uniform.

14. A method for producing a lighting module comprising:

situating a first plurality of light emitting elements of a first color, and a second 25 plurality of light emitting elements of a second color, upon a substrate; and providing an encapsulation layer that includes a first encapsulant and a second encapsulant, the first encapsulant being positioned above each of the light emitting elements of the first plurality, and the second encapsulant being positioned over the light emitting elements of the second plurality,

30 wherein the first encapsulant includes a concentration of wavelength conversion material that is substantially greater than a concentration of wavelength conversion material in the second encapsulant.

15. The method of claim 14, wherein the concentration of wavelength conversion material in the second encapsulant is substantially zero.

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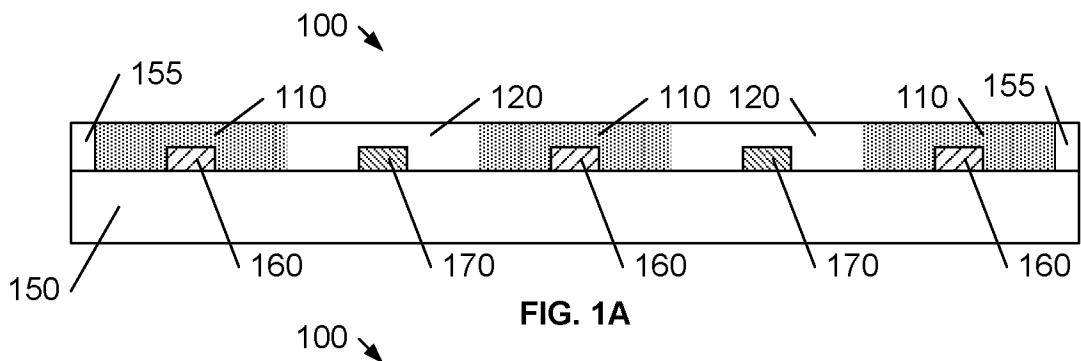


FIG. 1A

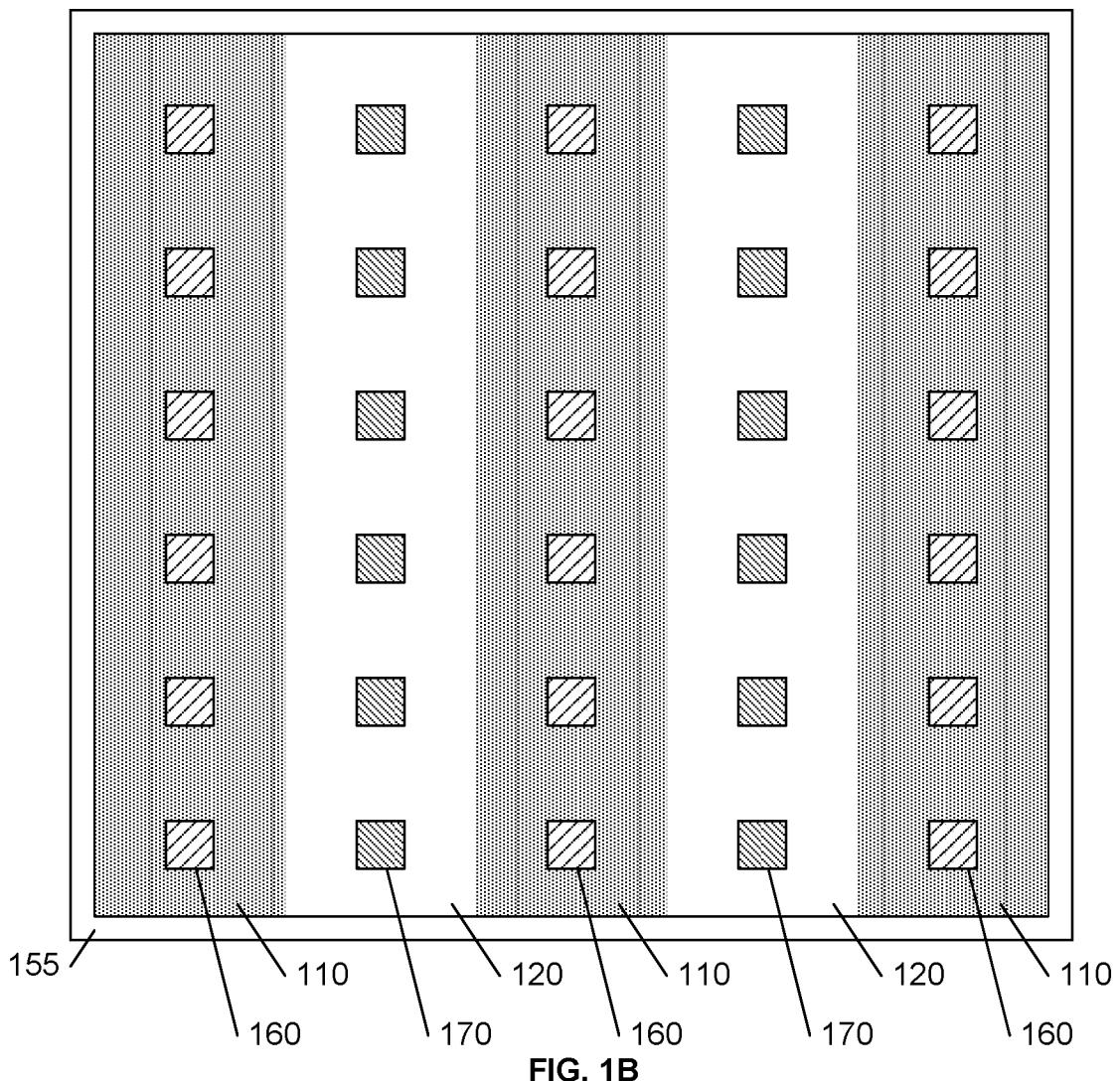


FIG. 1B

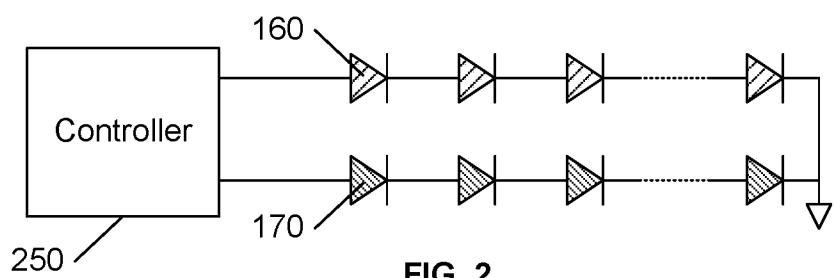


FIG. 2

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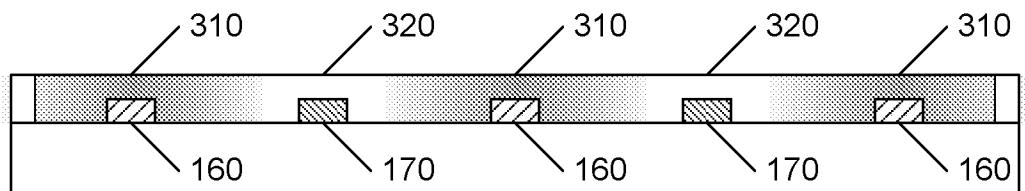


FIG. 3

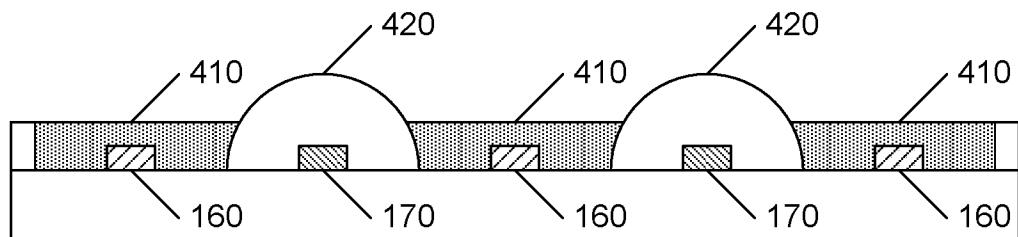


FIG. 4

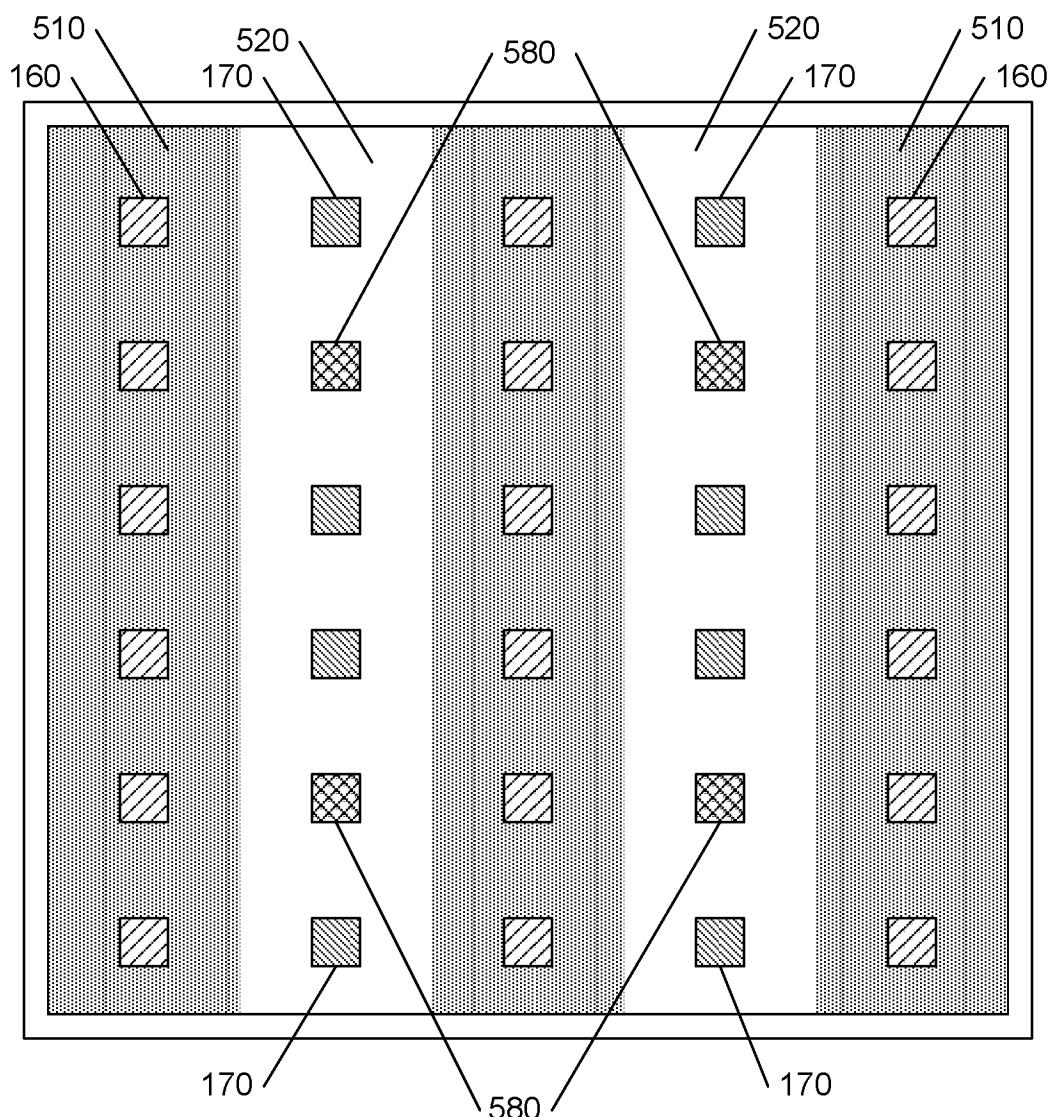


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/064070

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L25/075 H01L33/50 H01L33/52
ADD. H01L33/54

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F21K H01L H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X		

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2014	05/01/2015
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer De Kroon, Arnoud

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2014/064070

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