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**Li et al.**

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(54) **LED ARRAY PACKAGE COVERED WITH A HIGHLY THERMAL CONDUCTIVE PLATE**

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**H01L 33/00** (2010.01)

(52) **U.S. Cl.** ..... **257/98; 257/99; 257/100; 257/E33.061; 257/E33.075**

(58) **Field of Classification Search** ..... 257/98, 257/99, 100, E33.061, E33.075

See application file for complete search history.

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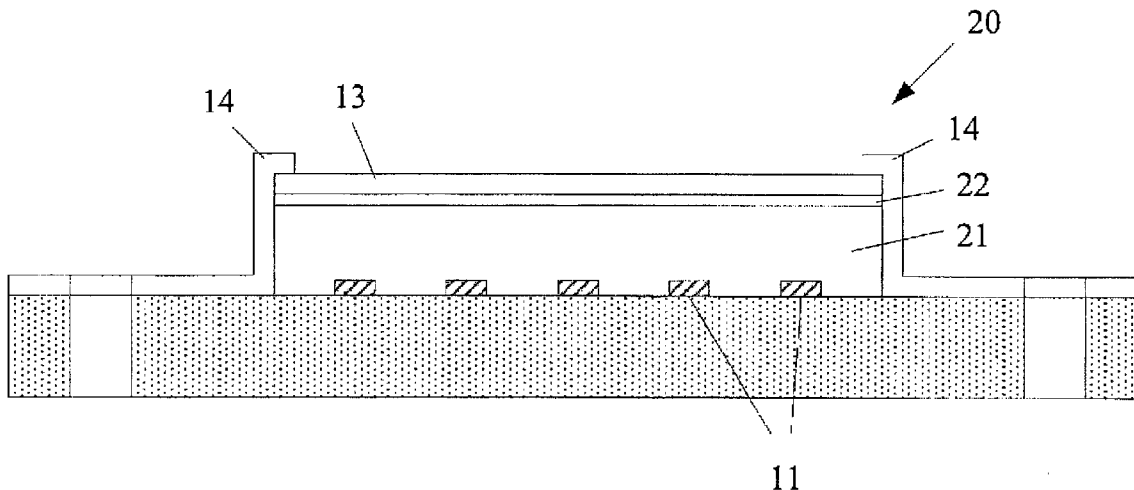
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(57) **ABSTRACT**

A light source includes a substrate, a light emitting diode on the substrate, and a phosphor layer over the light emitting diode. A plate is on the phosphor layer. An attachment member is coupled to the plate and is configured to conduct heat away from the plate.

**18 Claims, 15 Drawing Sheets**



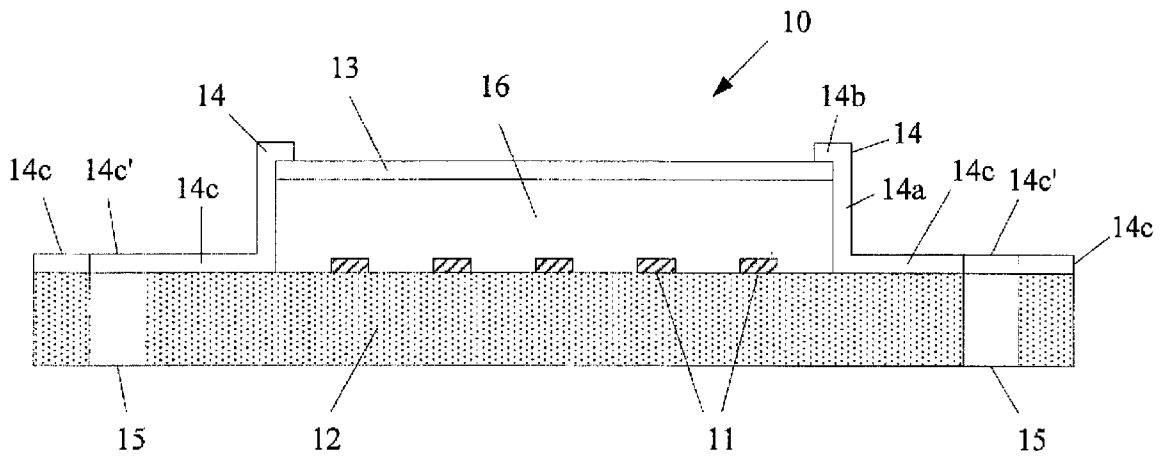


FIG. 1

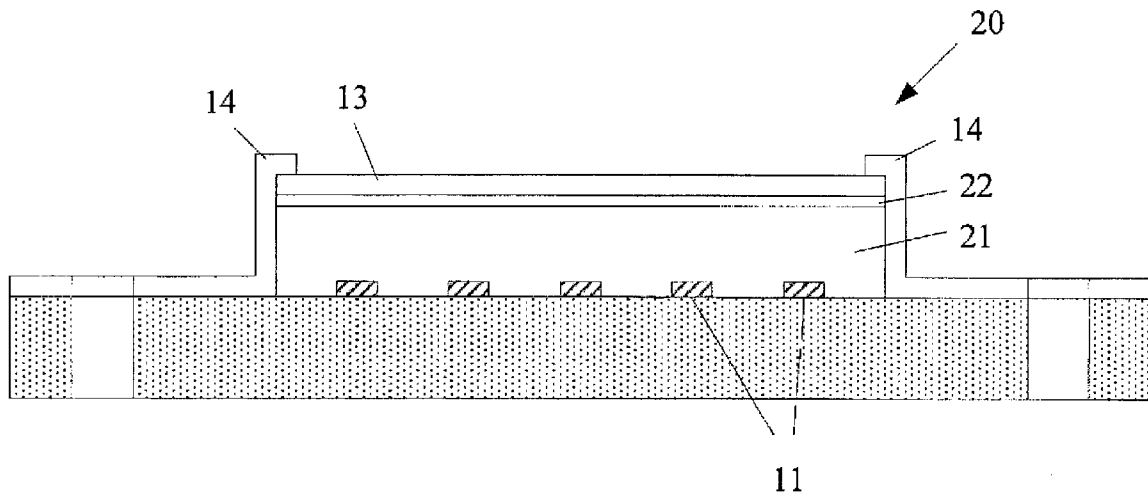


FIG. 2

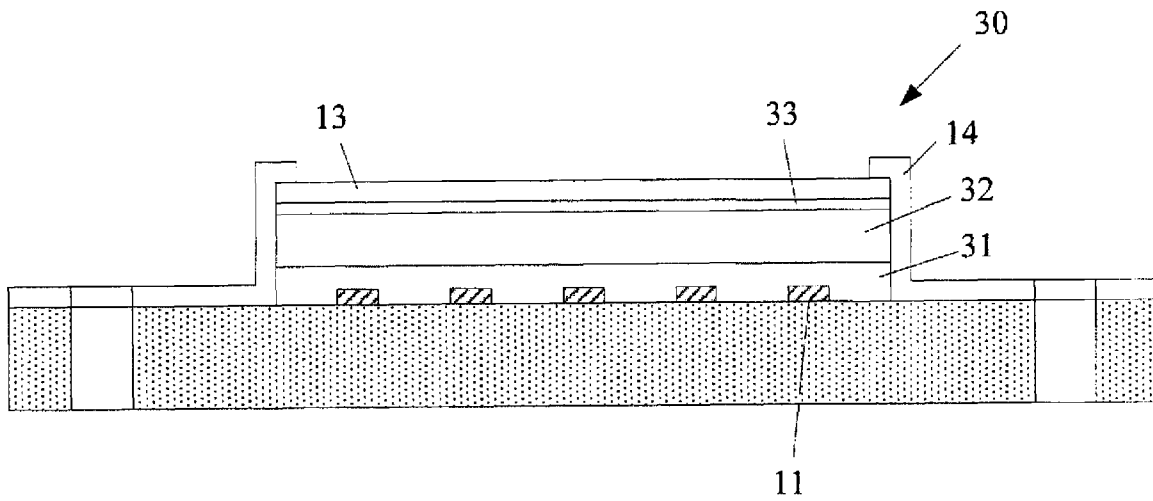


FIG. 3

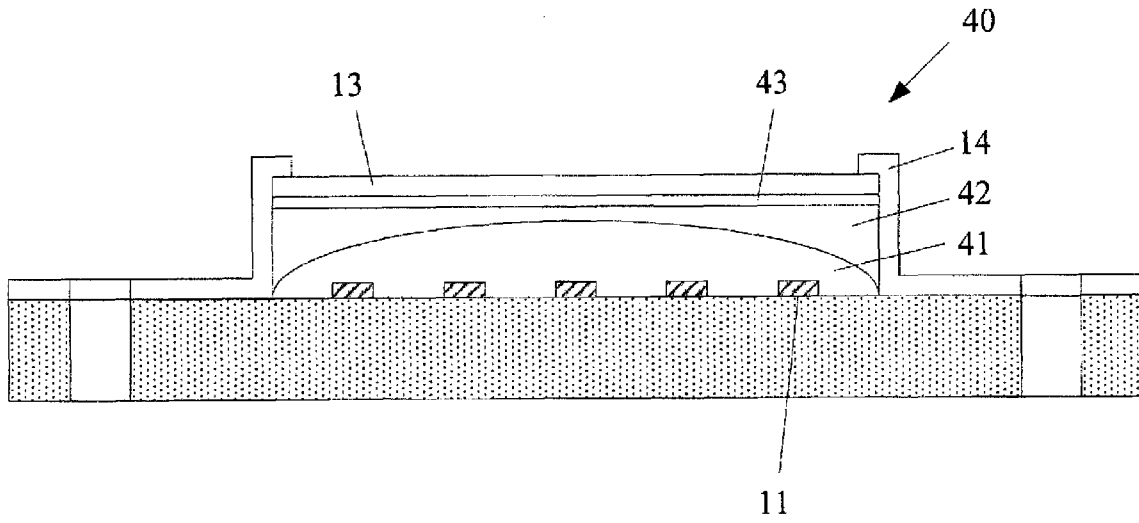
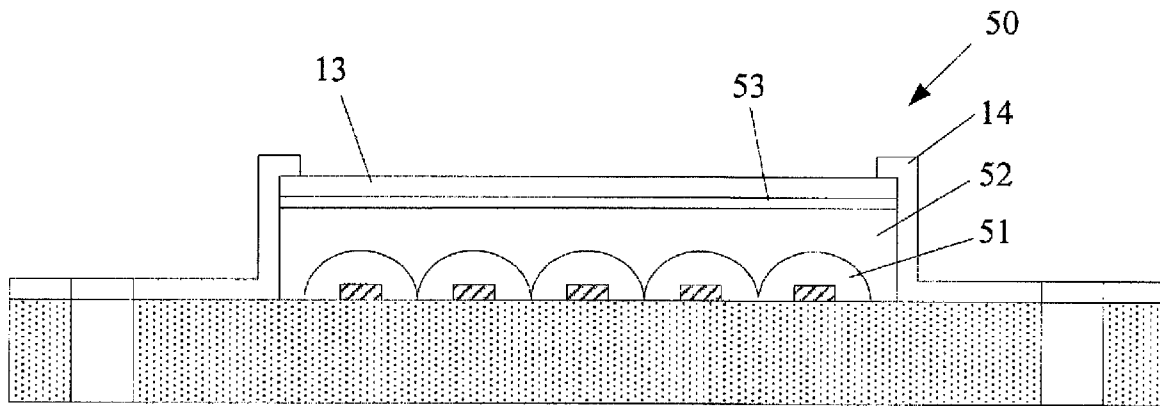


FIG. 4



11

FIG. 5

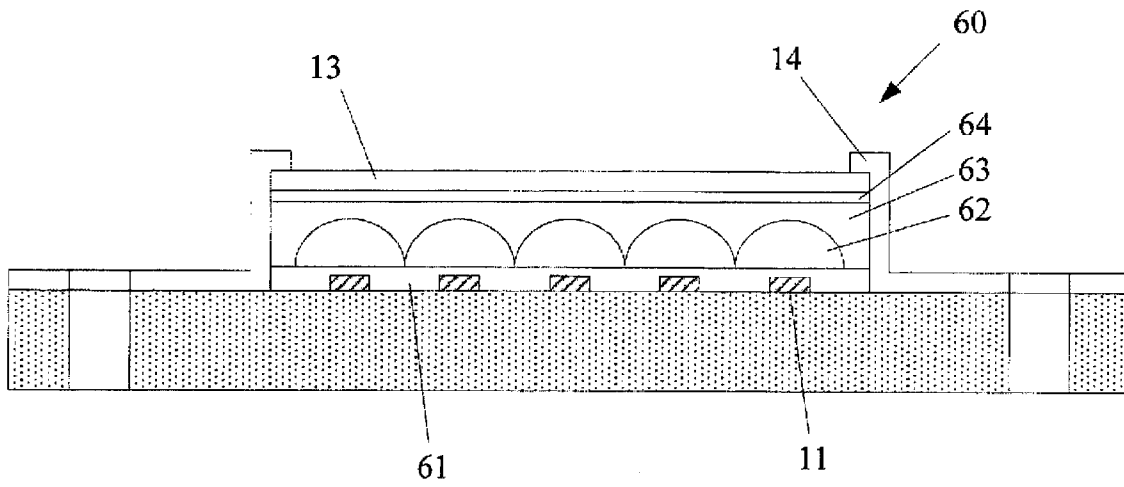


FIG. 6

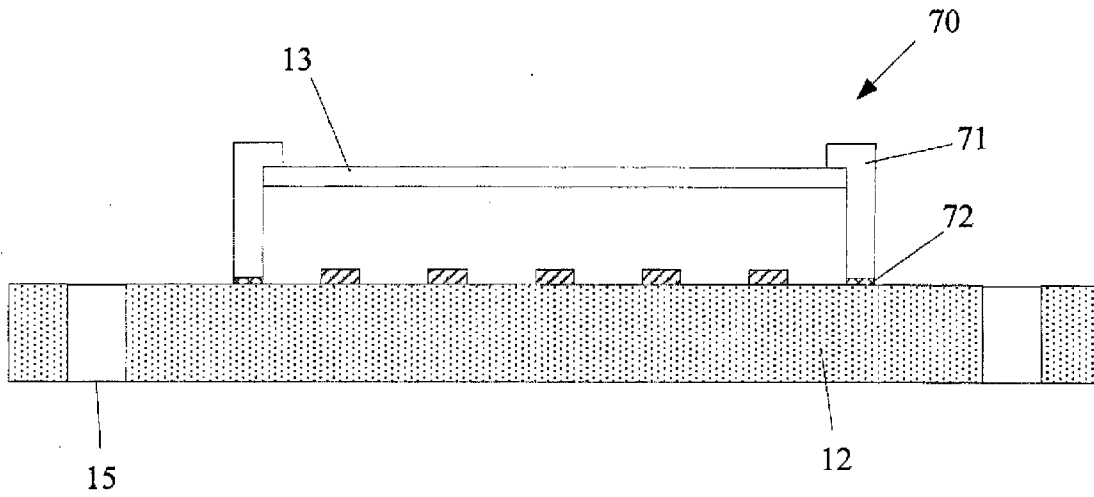


FIG. 7



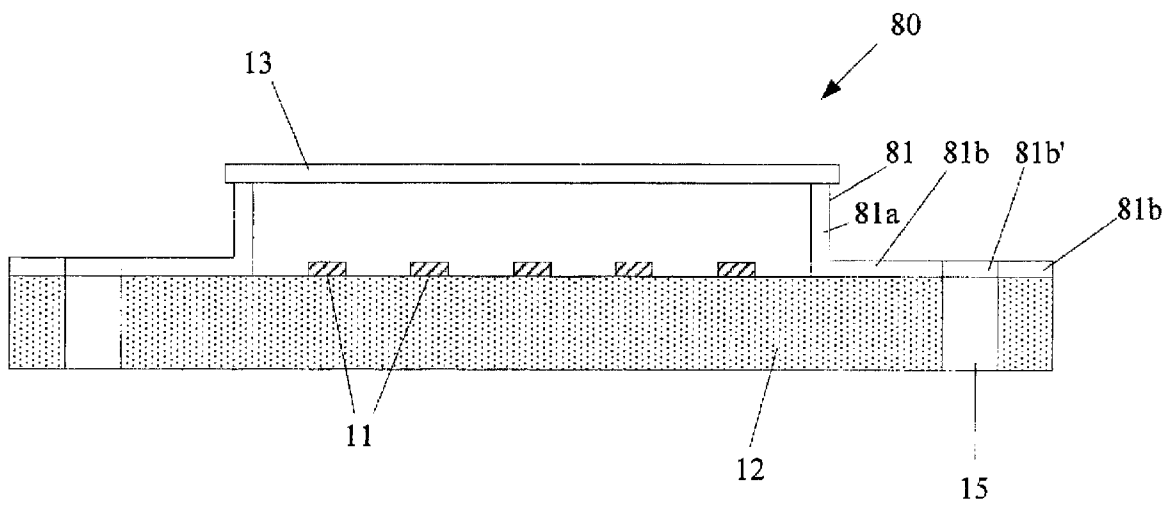


FIG. 8

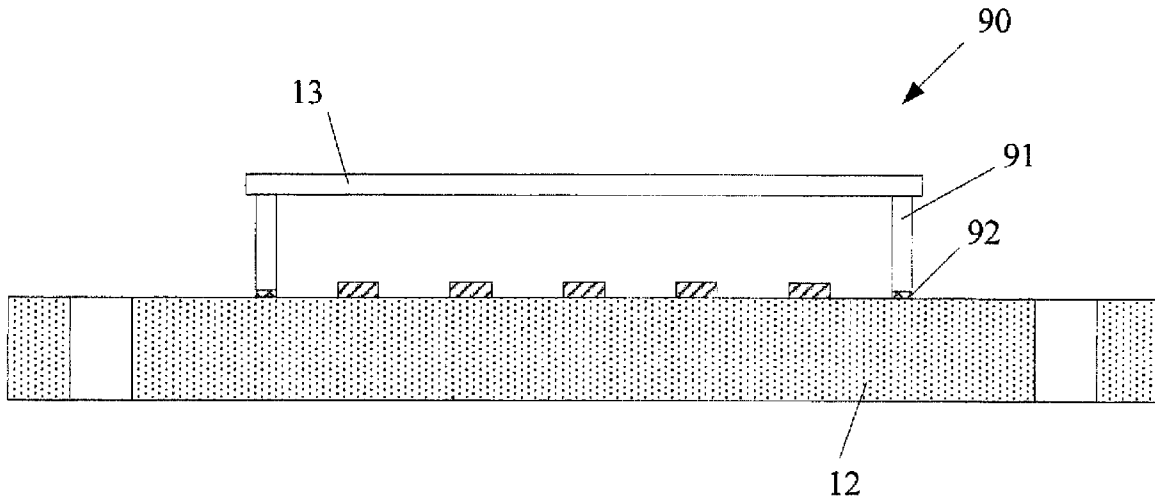


FIG. 9

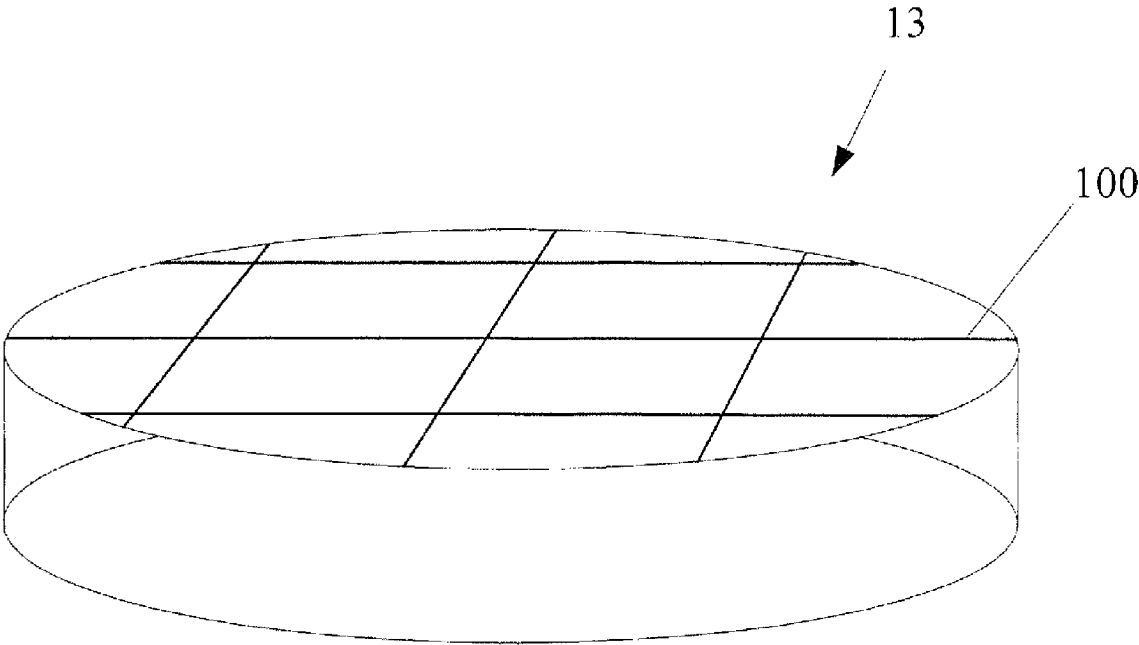


FIG. 10

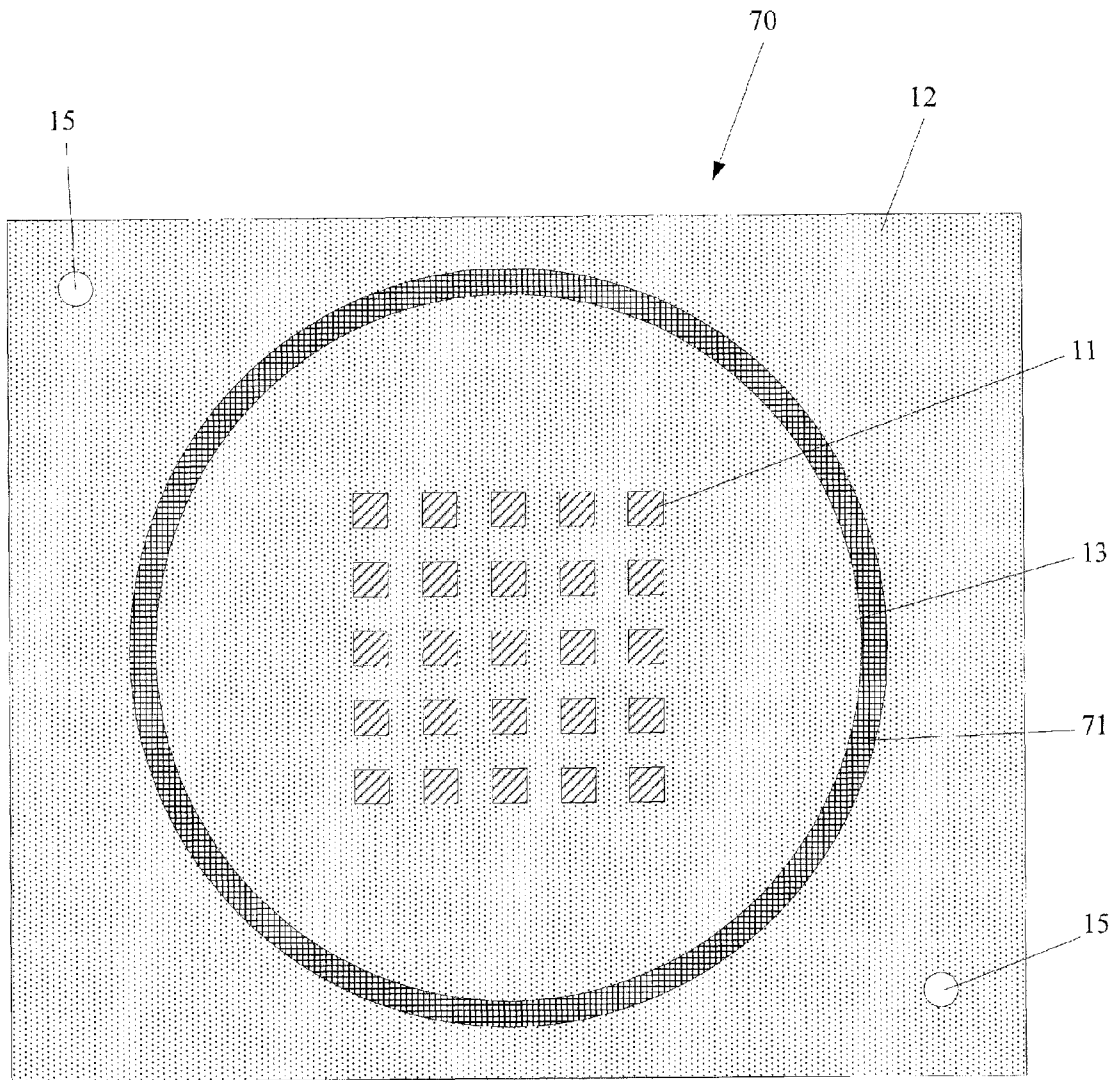


FIG. 11

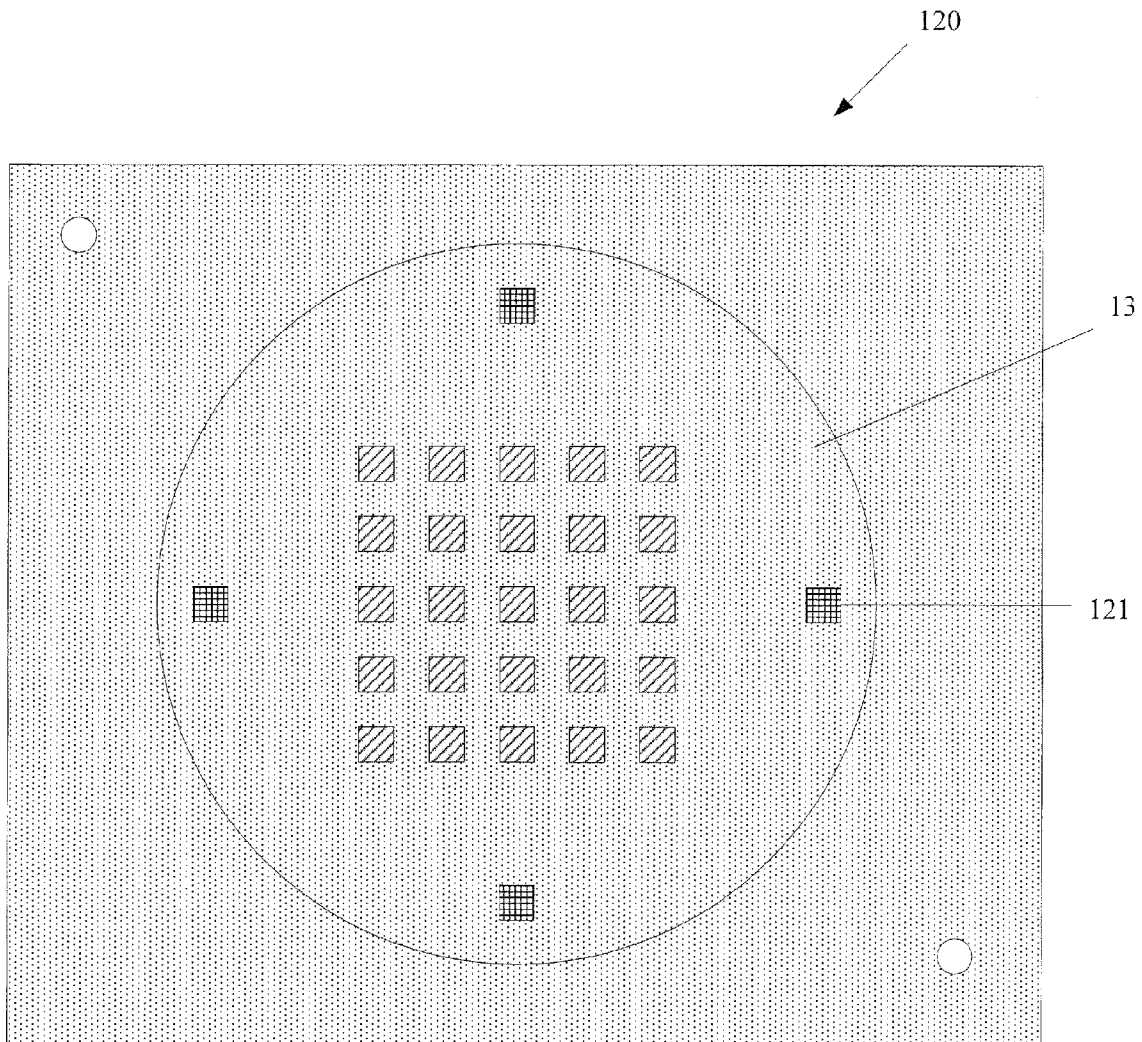


FIG. 12

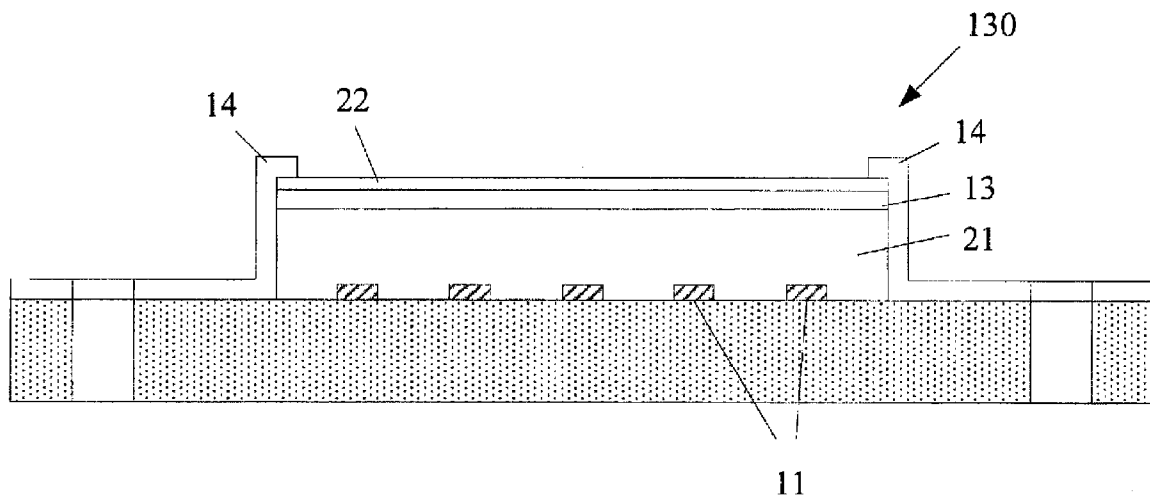


FIG. 13

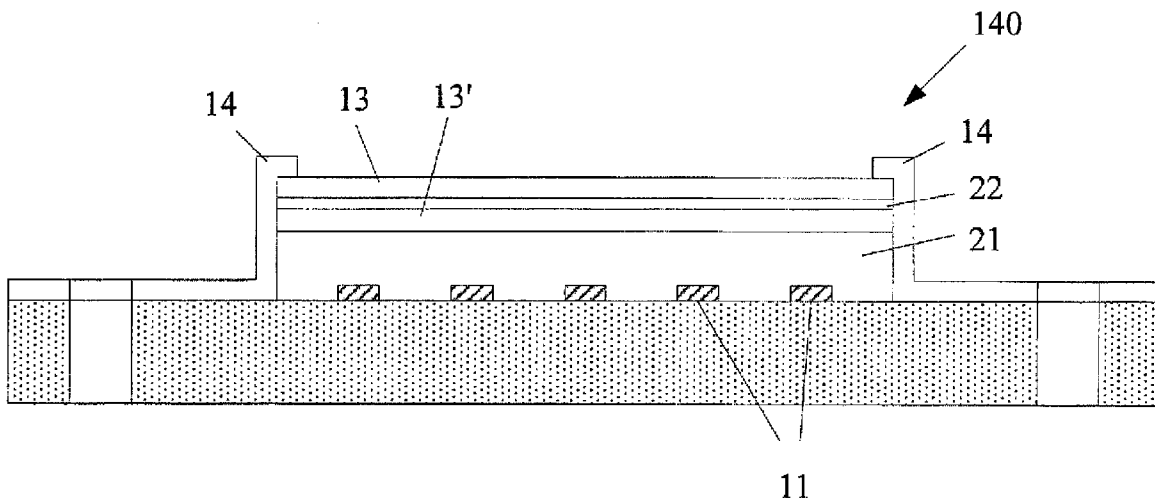


FIG. 14

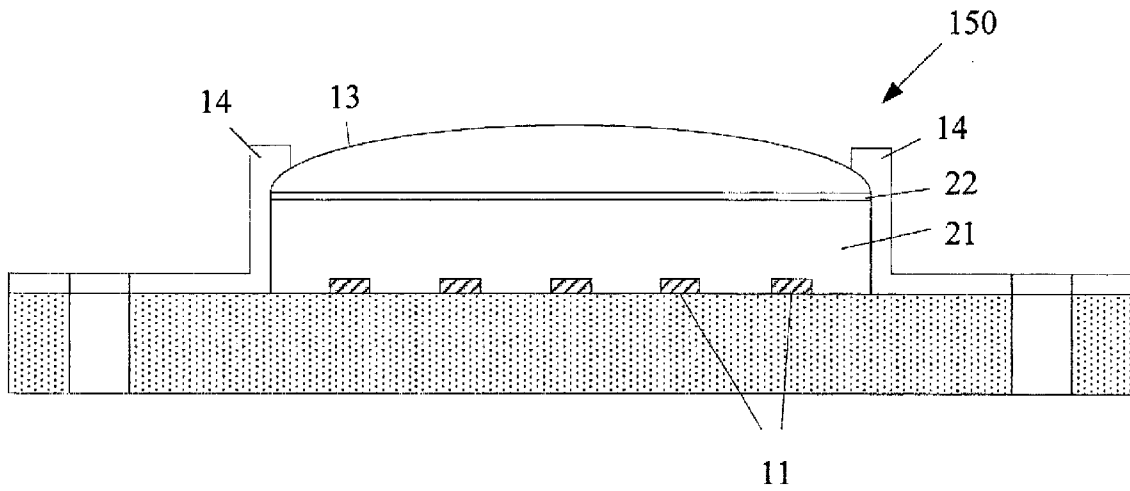


FIG. 15



## 1

**LED ARRAY PACKAGE COVERED WITH A  
HIGHLY THERMAL CONDUCTIVE PLATE**

## BACKGROUND

## 1. Field

The present disclosure relates to a light emitting diode (LED) array package and, more particularly, to an LED array package with a highly thermal conductive plate.

## 2. Description of Related Art

LEDs have been developed for many years and have been widely used in various light applications. As LEDs are lightweight, consume less energy, and have a good electrical power to light conversion efficiency, they have been used to replace conventional light sources, such as incandescent lamps and fluorescent light sources. LEDs may be utilized in an array package. For LED array packages, the temperature of a top surface of the package can reach 200° C. or more, which can damage the device. As such, there is a need in the art to improve the heat dissipation performance of LED array packages.

## SUMMARY

In one aspect of the disclosure, a light source includes a substrate, a light emitting diode on the substrate, and a phosphor layer over the light emitting diode. A plate is on the phosphor layer. An attachment member is coupled to the plate and is configured to conduct heat away from the plate.

In another aspect of the disclosure, a light source includes a substrate, a light emitting diode on the substrate, and a phosphor layer over the light emitting diode. The light source further includes first means for conducting heat away from the phosphor layer and second means for securing the first means to the light source and for conducting heat away from the first means.

It is understood that other aspects of an LED package (or LED array package) will become readily apparent to those skilled in the art from the following detailed description, wherein it is shown and described only exemplary configurations of an LED array package. As will be realized, the invention includes other and different aspects of an LED array package and the various details presented throughout this disclosure are capable of modification in various other respects, all without departing from the spirit and scope of the invention. Accordingly, the drawings and the detailed description are to be regarded as illustrative in nature and not as restrictive.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-section view of a first example of an LED array package according to a first configuration.

FIG. 2 is a cross-section view of a second example of an LED array package.

FIG. 3 is a cross-section view of a third example of an LED array package.

FIG. 4 is a cross-section view of a fourth example of an LED array package.

FIG. 5 is a cross-section view of a fifth example of an LED array package.

FIG. 6 is a cross-section view of a sixth example of an LED array package.

FIG. 7 is a cross-section view of an LED array package according to a second configuration.

FIG. 8 is a cross-section view of an LED array package according to a third configuration.

## 2

FIG. 9 is a cross-section view of an LED array package according to a fourth configuration.

FIG. 10 is a perspective view of the conductive glass plate.

FIG. 11 is a top view of the LED array package of FIG. 7.

FIG. 12 is a top view of an LED array package according to a fifth configuration.

FIG. 13 is a cross-sectional view of an LED array package according to a sixth configuration.

FIG. 14 is a cross-sectional view of an LED array package according to a seventh configuration.

FIG. 15 is a cross-sectional view of an LED array package according to an eighth configuration.

## DETAILED DESCRIPTION

Various aspects of the present invention will be described herein with reference to drawings that are schematic illustrations of idealized configurations of the present invention. As such, variations from the shapes of the illustrations as a result, for example, manufacturing techniques and/or tolerances, are to be expected. Thus, the various aspects of the present invention presented throughout this disclosure should not be construed as limited to the particular shapes of elements (e.g., regions, layers, sections, substrates, etc.) illustrated and described herein but are to include deviations in shapes that result, for example, from manufacturing. By way of example, an element illustrated or described as a rectangle may have rounded or curved features and/or a gradient concentration at its edges rather than a discrete change from one element to another. Thus, the elements illustrated in the drawings are schematic in nature and their shapes are not intended to illustrate the precise shape of an element and are not intended to limit the scope of the present invention.

It will be understood that when an element such as a region, layer, section, substrate, or the like, is referred to as being “on” another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being “directly on” another element, there are no intervening elements present. It will be further understood that when an element is referred to as being “formed” on another element, it can be grown, deposited, etched, attached, connected, coupled, or otherwise prepared or fabricated on the other element or an intervening element. In addition, when a first element is “coupled” to a second element, the first element may be directly connected to the second element or the first element may be indirectly connected to the second element with intervening elements between the first and second elements.

Furthermore, relative terms, such as “lower” or “bottom” and “upper” or “top,” may be used herein to describe one element’s relationship to another element as illustrated in the drawings. It will be understood that relative terms are intended to encompass different orientations of an apparatus in addition to the orientation depicted in the drawings. By way of example, if an apparatus in the drawings is turned over, elements described as being on the “lower” side of other elements would then be oriented on the “upper” side of the other elements. The term “lower” can therefore encompass both an orientation of “lower” and “upper,” depending of the particular orientation of the apparatus. Similarly, if an apparatus in the drawing is turned over, elements described as “below” or “beneath” other elements would then be oriented “above” the other elements. The terms “below” or “beneath” can therefore encompass both an orientation of above and below.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as

commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and this disclosure.

As used herein, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprise,” “comprises,” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The term “and/or” includes any and all combinations of one or more of the associated listed items.

Various aspects of an LED array package may be illustrated with reference to one or more exemplary configurations. As used herein, the term “exemplary” means “serving as an example, instance, or illustration,” and should not necessarily be construed as preferred or advantageous over other configurations of an LED array package disclosed herein.

Furthermore, various descriptive terms used herein, such as “on” and “transparent,” should be given the broadest meaning possible within the context of the present disclosure. For example, when a layer is said to be “on” another layer, it should be understood that one layer may be deposited, etched, attached, or otherwise prepared or fabricated directly or indirectly above or below that other layer. In addition, something that is described as being “transparent” should be understood as having a property allowing no significant obstruction or absorption of electromagnetic radiation in the particular wavelength (or wavelengths) of interest, unless a particular transmittance is provided.

FIG. 1 is a cross-section view of a first example of an LED array package 10 according to a first configuration. An LED is a semiconductor material impregnated, or doped, with impurities. These impurities add “electrons” and “holes” to the semiconductor, which can move in the material relatively freely. Depending on the kind of impurity, a doped region of the semiconductor can have predominantly electrons or holes, which is referred to as n-type or a p-type semiconductor region, respectively. In LED applications, the semiconductor includes an n-type semiconductor region and a p-type semiconductor region. A reverse electric field is created at the junction between the two regions, which cause the electrons and holes to move away from the junction to form an active region. When a forward voltage sufficient to overcome the reverse electric field is applied across the p-n junction, electrons and holes are forced into the active region and combine. When electrons combine with holes, they fall to lower energy levels and release energy in the form of light.

The light source may be configured to produce white light. White light may enable the light source to act as a direct replacement for conventional light sources used today in incandescent and fluorescent light sources. There are at least two common ways for producing white light. One way is to use individual LEDs that emit red, green, and blue, and then mix all the colors to produce white light. The other way is to use a phosphor material to convert monochromatic light emitted from a blue or ultra-violet (UV) LED to broad-spectrum white light. The present invention, however, may be practiced with other LED and phosphor combinations to produce different color lights.

As shown in FIG. 1, an array of LEDs 11 is on substrate 12. The array of LEDs 11 may be covered with a layer 16 of a

mixture of silicone and phosphor. U.S. patent application Ser. No. 12/164,506, entitled “A Light Emitting Device Having A Phosphor Layer” and which is herein incorporated by reference, provides several different additional configurations for the phosphor layer. A highly thermal conductive and transparent plate 13 is attached to a top surface of the LED array package 10 on the phosphor layer 16. The plate 13 may be a sapphire plate, a silicon carbide (SiC) plate, a chemical-vapor-deposition (CVD) diamond plate, CVD SiC on a glass plate, CVD diamond on a glass plate, a glass plate, a zinc oxide (ZnO) plate, a quartz plate, or any of the aforementioned types of plates with a metal net (see FIG. 10). The plate 13 is secured to the phosphor layer by attachment member(s) 14. The attachment member 14 includes a vertical member 14a that extends between the substrate 12 and the plate 13. The attachment member may further include a flange 14b that fits over and secures the plate 13. The attachment member 14 may be metal, such as aluminum, silver, copper, or another highly thermal conductive metal. The attachment member 14 may be in the shape of a ring and thermally bonded with the plate 13. The attachment member 14 may surround the LED array package 10 and have an extrusion 14c that extends parallel to the substrate 12 so that it can be thermally attached to the substrate 12. The extrusion 14c may include holes 14c', which allow the LED array package 10 to be attached to a heat sink on a bottom surface of the substrate 12 through aligned holes 15 in the substrate 12. The attachment member 14 may be secured to the substrate 12 with a thermal pad, epoxy, solder, or another adhesive, or may be secured with screws, bolts, or other fasteners through holes 14c'. Once the LED array package 10 is secured to a heat sink, the holes 14c', 15 may be filled with thermal grease or paste, thus providing a good thermal dissipation path from the plate 13, through the attachment member 14, to an attached heat sink. While FIG. 1 shows an array of LEDs, the plate 13 and attachment member 14 may be utilized with any number of LEDs including just one LED.

As discussed supra, for LED array packages, the temperature of a top surface of the LED array package 10 can reach 200° C. or more. The high temperature can significantly reduce the quantum efficiency of the phosphor or damage the whole device. With a 5x5 LED array package, the top surface of the LED array package can be significantly reduced with the highly thermal conductive plate 13 and an aluminum ring-shaped attachment member 14, as shown in FIG. 1.

FIG. 2 is a cross-section view of a second example of an LED array package 20. As shown in FIG. 2, the plate 13 and the attachment member 14 may be utilized with an LED array package 20 with a clear silicone layer 21 covering the LEDs 11 and a thin-film layer of phosphor 22 on the clear silicone layer 21.

FIG. 3 is a cross-section view of a third example of an LED array package 30. As shown in FIG. 3, the plate 13 and the attachment member 14 may be utilized with an LED array package 30 with a clear silicone layer 31 covering the LEDs 11, a thin-film layer of phosphor 33 attached to a bottom surface of the plate 13, and an intervening open air space 32 between the clear silicone layer 31 and the thin-film layer of phosphor 33.

FIG. 4 is a cross-section view of a fourth example of an LED array package 40. As shown in FIG. 4, the plate 13 and the attachment member 14 may be utilized with an LED array package 40 with a clear silicone dome layer 41 covering the LEDs 11, a thin-film layer of phosphor 43 attached to the bottom surface of the plate 13, and an intervening open air space 42 between the clear silicone dome layer 41 and the thin-film layer of phosphor 43. The LEDs 11 may be blue

5

LEDs. The clear silicone dome layer **41** extracts more blue light from the LED dies **11**, as less light is internally reflected at the interface of the air **42** and the clear silicone **41**.

FIG. **5** is a cross-section view of a fifth example of an LED array package **50**. As shown in FIG. **5**, the plate **13** and the attachment member **14** may be utilized with an LED array package **50** with a clear silicone dome (or half-ball lens) array **51** covering the LEDs **1**, a thin-film layer of phosphor **53** attached to the bottom surface of the plate **13**, and an intervening open air space **52** between the clear silicone dome array **51** and the thin-film layer of phosphor **53**. As discussed supra, the LEDs **11** may be blue LEDs. The clear silicone dome array **51** extracts more blue light from the LED dies **11**, as less light is internally reflected at the interface of the air **52** and the clear silicone **51**.

FIG. **6** is a cross-section view of a sixth example of an LED array package **60**. As shown in FIG. **6**, the plate **13** and the attachment member **14** may be utilized with an LED array package **60** with a clear silicone layer **61** covering the LEDs **11**, a clear dome (or half-ball lens) array **62** bonded onto the clear silicone layer **61**, a thin-film layer of phosphor **64** attached to the bottom surface of the plate **13**, and an intervening open air space **63** between the clear silicone layer **61** and the thin-film layer of phosphor **64**. The clear dome array **62** may be silicone, preformed glass, or preformed plastic such as polymethylmethacrylate (PMMA), polycarbonate, acrylic, or another transparent material. As discussed supra, the LEDs **11** may be blue LEDs. The clear dome array **62** extracts more blue light from the LED dies **11**, as less light is internally reflected at the interface of air **52** and the clear dome array **62**.

FIG. **7** is a cross-section view of an LED array package **70** according to a second configuration. As shown in FIG. **7**, the attachment member **71** may not include the extrusions of the attachment member **14**. The attachment member **71** may be attached to the substrate **12** with an epoxy, solder, or another adhesive **72** attached between the substrate **12** and the attachment member **71**.

FIG. **8** is a cross-section view of an LED array package **80** according to a third configuration. As shown in FIG. **8**, an array of LEDs **11** is on substrate **12**. A plate **13** may be attached to a top surface of the attachment member **81**. The plate **13** may be attached to the attachment member **81** with epoxy, solder, or another adhesive. The attachment member **81** includes a vertical member **81a** that extends between the substrate **12** and the plate **13**. The attachment member **81** may be metal, in the shape of a ring, and thermally bonded with the plate **13**. The attachment member **81** may surround the LED array package **80** and have an extrusion **81b** that extends parallel to the substrate **12** so that it can be thermally attached to the substrate **12**. The extrusion **81b** may include holes **81b'**, which allow the LED array package **80** to be attached to a heat sink on a bottom surface of the substrate **12** through aligned holes **15** in the substrate **12**. The attachment member **81** may be secured to the substrate **12** with a thermal pad, epoxy, solder, or another adhesive, or may be secured with screws, bolts, or other fasteners through holes **81b'**, **15**. Once the LED array package **80** is secured to a heat sink, the holes **81b'** may be filled with thermal grease or paste, thus providing a good thermal dissipation path from the plate **13** to an attached heat sink.

FIG. **9** is a cross-section view of an LED array package **90** according to a fourth configuration. As shown in FIG. **9**, the attachment member **91** may not include the extrusions of the attachment member **81**. The attachment member **91** may be

6

attached to the substrate **12** with an epoxy, solder, or another adhesive **92** attached between the substrate **12** and the attachment member **91**.

FIG. **10** is a perspective view of the highly thermal conductive plate **13**. As shown in FIG. **10**, the plate **13** may include a metal net **100** on a top surface. The metal net **100** may be aluminum, copper, silver, or another highly thermally conductive metal. The metal net **100** may be on an outer surface of the plate **13**, as shown in FIG. **10**, or may be within the glass plate **13**.

FIG. **11** is a top view of the LED array package **70** of FIG. **7**. As shown in FIG. **11**, the LED array package **70** includes a 5x5 array of LEDs **11** on substrate **12**. The ring-shaped attachment member **71** surrounds the LED array to secure the plate **13** (transparent in FIG. **11**) on a top surface of the LED array and to conduct heat away from the plate **13**. Holes **15** allow the LED array package **70** to be secured to a heat sink. Although FIG. **11** shows the attachment member **71** in the shape of a ring, the attachment member **71** may be separate components and may not entirely surround the LED array. In an alternate configuration, two or more components may be utilized to secure the plate **13** to the LED array package **70** at specific points along the edge of the plate **13**.

FIG. **12** is a top view of an LED array package **120** according to a fifth configuration. Alternatively, as shown in FIG. **12**, the LED array package **120** may include metal columns/walls **121** outside the LED array, and the plate **13** (transparent in FIG. **12**) may be secured to the metal columns/walls **121** with epoxy, solder, or another adhesive.

One of ordinary skill in the art would understand that the configurations of a silicone layer, a phosphor layer, and any intervening open air space over the LEDs **11** applies also to the second through fifth configurations of the attachment member. Furthermore, one of ordinary skill in the art would understand that the configurations can apply to any number of LEDs on a substrate, and therefore the configurations apply to a light emitting diode as well as to a light emitting diode array.

In one configuration, a light source includes a substrate, a light emitting diode on the substrate, a phosphor over the light emitting diode, a first means for conducting heat away from the phosphor layer, and a second means for securing the first means to the light source and for conducting heat away from the first means. The first means is the plate **13**. The second means may be the attachment member **14** (FIGS. **1-6**), **71** (FIGS. **7, 11**), **81** (FIG. **8**), or **91** (FIG. **9**) or may be the walls/columns **121** that extend vertically from the substrate as shown in FIG. **12**.

FIGS. **13, 14**, and **15** are cross-sectional views of LED array packages according to additional configurations. As shown in FIG. **13**, the plate **13** can be located between the phosphor layer **22** and the LEDs **11**. As shown in FIG. **14**, an additional plate **13'** may be located below the phosphor layer **22**, with the phosphor layer **22** sandwiched between the plate **13** and the plate **13'**. As shown in FIG. **15**, the plate **13** and the phosphor layer **22** can be dome-shaped.

The various aspects of this disclosure are provided to enable one of ordinary skill in the art to practice the present invention. Modifications to various aspects of an LED array package presented throughout this disclosure will be readily apparent to those skilled in the art, and the concepts disclosed herein may be extended to other applications. Thus, the claims are not intended to be limited to the various aspects of an LED array package presented throughout this disclosure, but are to be accorded the full scope consistent with the language of the claims. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known

to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for."

What is claimed is:

- 1. A light source, comprising:  
a substrate;  
a light emitting diode on the substrate;  
a phosphor layer over the light emitting diode;  
a plate on the phosphor layer; and  
an attachment member coupled to the plate and configured to conduct heat away from the plate, wherein the attachment member comprises a ring-shaped vertical member extending approximately perpendicular to the substrate and an extrusion extending outwardly from a bottom portion of the ring-shaped vertical member approximately parallel to the substrate; and the plate is attached to a top surface of the ring-shaped vertical member.
- 2. The light source of claim 1, wherein the plate is transparent.
- 3. The light source of claim 1, wherein the plate contacts the phosphor layer.
- 4. The light source of claim 1, wherein the attachment member is configured to secure the plate to the light source.
- 5. The light source of claim 1, wherein the plate comprises a sapphire plate, a silicone carbide plate, a chemical-vapor-deposition diamond plate, chemical-vapor-deposition silicon carbide on a glass plate, chemical-vapor-deposition diamond on a glass plate, a glass plate, a zinc oxide plate, or a quartz plate.
- 6. The light source of claim 5, wherein the plate further comprises a metal net.
- 7. The light source of claim 1, wherein the attachment member is metal.
- 8. The light source of claim 1, wherein the attachment member comprises a ring-shaped vertical member extending approximately perpendicular to the substrate, a bottom surface of the ring-shaped vertical member is attached to the substrate with an adhesive, and the plate is attached to a top surface of the ring-shaped vertical member.

9. The light source of claim 1, wherein the extrusion is attached to the substrate with an adhesive.

10. The light source of claim 1, wherein the extrusion and the substrate each have at least one hole that are aligned together.

11. The light source of claim 1, wherein the attachment member comprises at least one column or wall and the plate is attached to said at least one column or wall.

12. The light source of claim 1, further comprising at least one additional light emitting diode on the substrate; wherein said light emitting diode and said at least one additional light emitting diode are in an array on the substrate, and said phosphor layer is also over said at least one additional light emitting diode.

13. The light source of claim 1, wherein the phosphor layer is between the plate and the light emitting diode.

14. The light source of claim 1, wherein the plate is between the phosphor layer and the light emitting diode.

15. The light source of claim 1, wherein the plate is dome-shaped.

16. The light source of claim 1, further comprising a second plate below the phosphor layer, the phosphor layer being between the plate and the second plate.

17. A light source, comprising:  
a substrate;  
a light emitting diode on the substrate;  
a phosphor layer over the light emitting diode;  
a plate on the phosphor layer; and

an attachment member coupled to the plate and configured to conduct heat away from the plate, the attachment member comprising a ring-shaped vertical member extending approximately perpendicular to the substrate and a flange extending inwardly from a top portion of the ring-shaped vertical member approximately parallel to the substrate; wherein a bottom surface of the ring-shaped vertical member is attached to the substrate with an adhesive; and the flange extends over an edge of the plate to secure the plate to the light source.

18. The light source of claim 17, further comprising an extrusion extending outwardly from a bottom portion of the ring-shaped vertical member approximately parallel to the substrate.

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