(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 August 2012 (09.08.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/106312 A1

(51) International Patent Classification:
H01L 33/48 (2010.01)

(21) International Application Number:
PCT/US2012/023285

(22) International Filing Date:
31 January 2012 (31.01.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/019,812 2 February 2011 (02.02.2011) US

(71) Applicant *(for all designated States except US)*: **CREE, INC.** [US/US]; 4600 Silicon Drive, Durham, NC 27703-8475 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **EMERSON, David, T.** [US/US]; 5519 New Rise Court, Chapel Hill, NC 27516 (US). **HUSSELL, Christopher, P.** [US/US]; 101 Glenmore Road, Cary, NC 27519 (US). **JOO, Sung, Chul** [KR/US]; 253 Seymour Place, Cary, NC 27519 (US).

(74) Agent: **WILSON, Jeffrey, L.**; Jenkins, Wilson, Taylor & Hunt, P.A., Suite 1200, University Tower, 3100 Tower Boulevard, Durham, NC 27707 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title**: LIGHT EMITTING DEVICE PACKAGES, SYSTEMS, AND METHODS

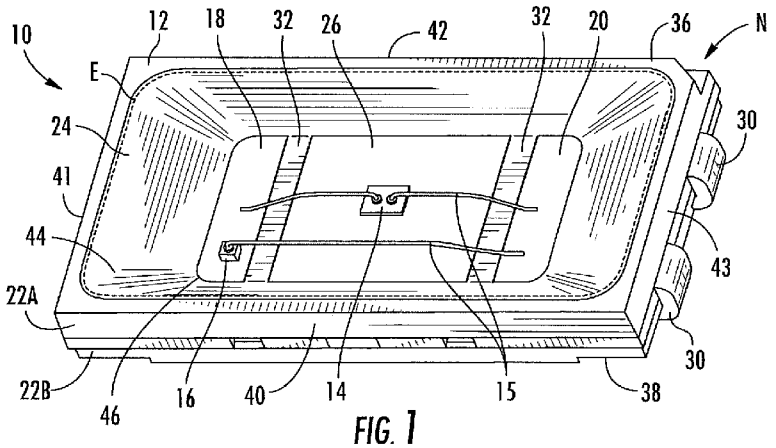


FIG. 1

(57) **Abstract**: Packages, systems and methods for light emitting devices are disclosed. An LED package in one aspect can be of various sizes and configurations and can include one or more LEDs of a size smaller than those typically provided. The LED package or packages can for example be used for backlighting or other lighting fixtures. Optimized materials and techniques can be used for the LED packages to provide energy efficiency and long lifetime.

WO 2012/106312 A1

DESCRIPTION

LIGHT EMITTING DEVICE PACKAGES, SYSTEMS, AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Continuation-in-Part Patent Application Serial Number 13/019,812 filed February 2, 2011, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The subject matter disclosed herein relates generally to light emitting device packages, systems, and methods. More particularly, the subject matter disclosed herein relates to light emitting diode (LED) packages, systems and methods with optimized components and proportions.

BACKGROUND

Solid state light sources, such as light emitting diodes (LEDs) are widely used in flat display panels for monitors, televisions, and/or other displays. LEDs can be used in the design of thinner, energy-saving backlighting systems for use with liquid crystal display (LCD) devices. Backlighting and/or other display panel systems using LEDs require less power to meet the brightness specifications for backlighting applications, thereby significantly reducing energy consumption and the need for active cooling systems. Conventional backlighting displays typically include a plurality of LEDs or LED packages mounted over an illumination panel. Conventional LED packages used in backlighting can comprise one or more large LED chips mounted in packages with a large thickness in combination with smaller cavity depth to thickness ratios. That is, cavity depth of conventional packages can comprise a small percentage of the overall thickness. A current need in display panel system technologies exists for thinner LED packages capable of maintaining brightness specifications for the manufacture and market of thinner, lighter products to consumers. Further need exists for thinner packages where the cavity depth is a larger percentage of the package to maintain reflection of light, thus, maintaining brightness levels. Conventional LED packages used in

backlighting can also utilize silicone, epoxy or solder die attach. Such die attach methods can result in the LEDs becoming at least partially detached from the package during operation or experience squeeze out of the bonding materials. Such defects can lead to light failure and/or thermal breakdown of the LEDs during operation.

Despite the availability of various light emitting device packages in the marketplace, a need remains for LED packages, systems and methods with optimized components and proportions versus those currently available.

SUMMARY

In accordance with this disclosure, light emitting device packages, systems, and methods are provided with optimized components and proportions. It is, therefore, an object of the present disclosure herein to provide thin, bright light emitting device packages utilizing robust die attach methods.

These and other objects of the present disclosure as can become apparent from the disclosure herein are achieved, at least in whole or in part, by the subject matter described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present subject matter including the best mode thereof to one of ordinary skill in the art is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

Figure 1 illustrates a perspective top view of an embodiment of an LED package according to the subject matter herein;

Figure 2 illustrates a top plan view of an embodiment of an LED package according to the subject matter herein;

Figure 3 illustrates a side view of an embodiment of an LED package according to the subject matter herein;

Figure 4 illustrates a perspective bottom view of an embodiment of a LED package according to the subject matter herein;

Figure 5 illustrates a cross-sectional view of an embodiment of a LED package according to the subject matter herein;

Figures 6A and 6B illustrate top plan views of an embodiment of an LED package according to the subject matter herein;

Figure 7 illustrates a top plan view of an embodiment of an LED package according to the subject matter herein;

Figure 8 illustrates a perspective top view of a leadframe disposed within a LED package according to the subject matter herein;

Figure 9 illustrates a cross-sectional view of an embodiment of an LED package according to the subject matter herein;

Figures 10A and 10B illustrate side views of an embodiment of a LED package according to the subject matter herein;

Figure 11 is a side view of a portion of an LED package showing a mounted LED according to the subject matter herein;

Figures 12A and 12B illustrate side views of embodiments of thermal elements of LED package according to the subject matter herein;

Figures 13A and 13B illustrate side views of LED die attach methods according to the subject matter herein;

Figure 14 illustrates a LED backlighting system according to the subject matter herein;

Figures 15A and 15B illustrate side views of a LED backlighting system according to the subject matter herein; and

Figure 16 illustrates a side view of an illumination panel used in a LED backlighting system according to the subject matter herein.

DETAILED DESCRIPTION

Reference will now be made in detail to possible aspects or embodiments of the subject matter herein, one or more examples of which are shown in the figures. Each example is provided to explain the subject matter and not as a limitation. In fact, features illustrated or described as part of one embodiment can be used in another embodiment to yield still a further embodiment. It is intended that the subject matter disclosed and envisioned herein covers such modifications and variations.

As illustrated in the various figures, some sizes of structures or portions are exaggerated relative to other structures or portions for illustrative purposes and, thus, are provided to illustrate the general structures of the present subject matter. Furthermore, various aspects of the present subject matter are described with reference to a structure or a portion being formed on other structures, portions, or both. As will be appreciated by those of skill in the art, references to a structure being formed "on" or "above" another structure or portion contemplates that additional structure, portion, or both may intervene. References to a structure or a portion being formed "on" another structure or portion without an intervening structure or portion are described herein as being formed "directly on" the structure or portion. Similarly, it will be understood that when an element is referred to as being "connected", "attached", or "coupled" to another element, it can be directly connected, attached, or coupled to the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly connected", "directly attached", or "directly coupled" to another element, no intervening elements are present.

Furthermore, relative terms such as "on", "above", "upper", "top", "lower", or "bottom" are used herein to describe one structure's or portion's relationship to another structure or portion as illustrated in the figures. It will be understood that relative terms such as "on", "above", "upper", "top", "lower" or "bottom" are intended to encompass different orientations of the device in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, structure or portion described as "above" other structures or portions would now be oriented "below" the other structures or portions. Likewise, if devices in the figures are rotated along an axis, structure or portion described as "above", other structures or portions would now be oriented "next to" or "left of" the other structures or portions. Like numbers refer to like elements throughout.

Light emitting devices according to embodiments described herein may comprise group III-V nitride (e.g., gallium nitride) based light emitting diodes (LEDs) or lasers fabricated on a growth substrate, for example, silicon carbide substrate, such as those devices manufactured and sold by Cree, Inc. of Durham, North Carolina. For example, Silicon carbide (SiC) substrates/layers

discussed herein may be 4H polytype silicon carbide substrates/layers. Other silicon carbide candidate polytypes, such as 3C, 6H, and 15R polytypes, however, may be used. Appropriate SiC substrates are available from Cree, Inc., of Durham, N.C., the assignee of the present subject matter, and the methods for producing such substrates are set forth in the scientific literature as well as in a number of commonly assigned U.S. patents, including but not limited to U.S. Patent No. Re. 34,861; U.S. Patent No. 4,946,547; and U.S. Patent No. 5,200,022, the disclosures of which are incorporated by reference herein in their entireties.

As used herein, the term "Group III nitride" refers to those semiconducting compounds formed between nitrogen and one or more elements in Group III of the periodic table, usually aluminum (Al), gallium (Ga), and indium (In). The term also refers to binary, ternary, and quaternary compounds such as GaN, AlGaN and AlInGaN. The Group III elements can combine with nitrogen to form binary (e.g., GaN), ternary (e.g., AlGaN), and quaternary (e.g., AlInGaN) compounds. These compounds may have empirical formulas in which one mole of nitrogen is combined with a total of one mole of the Group III elements. Accordingly, formulas such as AlxGa1-xN where 1>x>0 are often used to describe these compounds. Techniques for epitaxial growth of Group III nitrides have become reasonably well developed and reported in the appropriate scientific literature, and in commonly assigned U.S. Patent No. 5,210,051, U.S. Patent No. 5,393,993, and U.S. Patent No. 5,523,589, the disclosures of which are hereby incorporated by reference herein in their entireties.

Although various embodiments of LEDs disclosed herein comprise a growth substrate, it will be understood by those skilled in the art that the crystalline epitaxial growth substrate on which the epitaxial layers comprising an LED are grown may be removed, and the freestanding epitaxial layers may be mounted on a substitute carrier substrate or submount which may have better thermal, electrical, structural and/or optical characteristics than the original substrate. The subject matter described herein is not limited to structures having crystalline epitaxial growth substrates and may be used in connection with structures in which the epitaxial layers have been removed

from their original growth substrates and bonded to substitute carrier substrates.

Group III nitride based LEDs according to some embodiments of the present subject matter, for example, may be fabricated on growth substrates (such as a silicon carbide substrates) to provide horizontal devices (with both electrical contacts on a same side of the LED) or vertical devices (with electrical contacts on opposite sides of the LED). Moreover, the growth substrate may be maintained on the LED after fabrication or removed (e.g., by etching, grinding, polishing, etc.). The growth substrate may be removed, for example, to reduce a thickness of the resulting LED and/or to reduce a forward voltage through a vertical LED. A horizontal device (with or without the growth substrate), for example, may be flip chip bonded (e.g., using solder) to a carrier substrate or printed circuit board (PCB), or wire bonded. A vertical device (without or without the growth substrate) may have a first terminal solder bonded to a carrier substrate, mounting pad, or PCB and a second terminal wire bonded to the carrier substrate, electrical element, or PCB. Examples of vertical and horizontal LED chip structures are discussed by way of example in U.S. Publication No. 2008/0258130 to Bergmann et al. and in U.S. Publication No. 2006/0186418 to Edmond et al., the disclosures of which are hereby incorporated by reference herein in their entireties.

Solid state light LEDs may be used individually or in combinations, optionally together with one or more luminescent materials (e.g., phosphors, scintillators, lumiphoric inks) and/or filters, to generate light of desired perceived colors (including combinations of colors that may be perceived as white). Inclusion of luminescent (also called 'lumiphoric') materials in LED devices may be accomplished by adding such materials to encapsulants, adding such materials to lenses, or by direct coating onto LEDs. Other materials, such as dispersers and/or index matching materials may be disposed in such encapsulants.

The LED can be coated, at least partially, with one or more phosphors with the phosphors absorbing at least a portion of the LED light and emitting a different wavelength of light such that the LED emits a combination of light from the LED and the phosphor. In one embodiment, the LED emits a white light

combination of LED and phosphor light. The LED can be coated and fabricated using many different methods, with one suitable method being described in U.S. Patent Application Serial Nos. 11/656,759 and 11/899,790, both entitled "Wafer Level Phosphor Coating Method and Devices Fabricated Utilizing Method", and both of which are incorporated herein by reference. In the alternative, LEDs can be coated using other methods such an electrophoretic deposition (EPD), with a suitable EPD method described in U.S. patent application Ser. No. 11/473,089 entitled "Close Loop Electrophoretic Deposition of Semiconductor Devices", which is also incorporated herein by reference. It is understood that LED devices and methods according to the present subject matter can also have multiple LEDs of different colors, one or more of which may be white emitting.

Referring now to Figures 1 to 16, Figures 1 to 5 illustrate a first embodiment of a light emitting device package, for example an LED package, generally designated **10**. Referring to Figures 1 to 4, LED package **10** can comprise a body structure, or body **12**, housing one or more LED chips, or LEDs **14** arranged over an upper surface of a thermal element described further herein. An electrostatic discharge (ESD) protection device **16** can be disposed in the LED package **10** to protect the package from ESD damage. In one aspect, ESD protection device **16** can comprise a Zener diode, ceramic capacitor, transient voltage suppression (TVS) diode, multilayer varistor, a Shottky diode, a different LED arranged reverse biased to LEDs **16** and/or any other suitable ESD protection device known in the art. ESD protection device **16** can be mounted over an electrical element and electrically connected to a second electrical element of a different electrical polarity. For example, first and second electrical elements can comprise first and second electrical leads **18** and **20**, respectively. One of first and second electrical leads **18** and **20** can comprise an anode, and the other a cathode for allowing electrical signal, or current, to flow into the LED package and illuminate the one or more LEDs **14** when connected to an external circuit or other suitable source of electrical current. First and second electrical leads **18** and **20** can be formed of any suitable electrically conducting material. In one aspect, first and second electrical leads **18** and **20** can be formed from a leadframe comprising a single

metal and/or layers of metals, for example including but not limited to, silver, copper, platinum, nickel, and/or any combination thereof.

Body **12** can be advantageously formed using a molding process, such as injection molding, using a thermoplastic and/or thermoset material that can be electrically insulating. Polymer-containing materials can be used to form the body **12**, with such materials optionally being reinforced (e.g., with fibers, ceramics, or composites). Body **12** can be white or light in color to minimize dark appearance of the overall package. Ceramic and/or composite materials may be utilized in place of polymers to form body **12** in certain embodiments. As an alternative to injection molding, other types of molding and/or forming processes (e.g., sintering) may be used. Body **12** can comprise an upper portion **22A** and lower portion **22B** (e.g., as may be formed in upper and lower molding die portions (not shown), respectively). A reflector cavity **24** can be formed about electrical elements and thermal element as the inverse of a central protrusion in an upper molding die. In one aspect, thermal element can comprise a thermal heat transfer material **26** over which the one or more LEDs **14** can be directly and/or indirectly mounted. As Figure 3 illustrates, lower portion **22B** can taper inwardly and away from the external portions of the metal leads, for example, one or more external portions **28** corresponding to first electrical lead **18** and one or more external portions **30** corresponding to second electrical lead **20**.

Body **12** can comprise a body selected from a group of materials consisting of molded plastic, polymeric, thermoset plastic, thermoplastic, ceramic, nylon, liquid crystal polymer (LCP), or polyvinyl chloride (PVC) wherein body **12** can be disposed around thermal and electrical elements. In one aspect, body **12** can comprise a white plastic material, more specifically, a molded white plastic material. In one aspect, body **12** can comprise any suitable moldable material. In another aspect, body **12** can comprise a plastic material having quantitative and qualitative properties optimized for solid state device package applications. The plastic material can in one aspect comprise, for example, any suitable organic polymer, such as for example a heat resistant

resin such as a polyamide resin. The plastic material can be filled with glass or mineral material for strength and something like titanium dioxide for reflectivity.

Utilizing a plastic material such as described herein for body **12** of package **10** can allow for an advantageous softness for body **12** at operating temperatures as hardness can depend upon temperature. This softness allows body **12** to desirably have improved reliability and useful lifetime. The plastic material can in one aspect be a liquid crystal polymer (LCP). An optimized plastic material in accordance herewith can have a glass transition temperature (T_g) that can, for example, be greater than approximately 110 degrees Celsius (°C). The glass transition temperature (T_g) can, for example, be greater than approximately 115°C or greater than approximately 120°C. In one aspect, the glass transition temperature (T_g) can be greater than approximately 123°C. The optimized plastic material in accordance herewith can also comprise a melting point temperature (T_m) that can be less than approximately 315°C. The melting point temperature (T_m) can, for example, be less than approximately 310°C. The melting point temperature (T_m) can, for example, be less than approximately 300°C. In one aspect, the melting point temperature (T_m) can be approximately 307°C. A plastic material with a T_g of approximately 123°C is higher than many plastics conventionally used and can allow the package to have increased stability at elevated temperatures. A plastic material with a lower T_m of approximately 307°C can allow better flowability because the melting temperature is lower than that of plastics conventionally used and the plastic body is easier to mold. The plastic selected for body **12** can also comprise optimized qualitative properties. For example, a white plastic material can be chosen which exhibits a better reflectivity retention value while also exhibiting fewer tendencies to discolor, degrade, and/or yellow when subjected to heat and/or light exposure. The reflectivity of the plastic material can in one aspect be greater than 90% for example, and that level or another level of high reflectivity can be maintained over time, heat, moisture, and blue light exposure.

Other characteristics or features of the plastic material for body **12** can comprise an elongation value (mechanical property) of approximately 1.4% or greater, or an elongation value of 1.6% or greater. In one aspect, the

elongation value can be approximately 1.5% or greater. Also as a mechanical property, the flexural strength of the plastic material of body **12** as measured by ASTM D790 standards can be approximately 150 MPa or lower, approximately 130 MPa or lower, or approximately 120 MPa or lower. In one aspect, the flexural strength of the plastic material of body **12** can be approximately 140 MPa or lower as measured by ASTM D790 standards. Also as a mechanical property, the flexural modulus of the plastic material of body **12** can be approximately 6.9 GPa or lower, or approximately 6.5 GPa or lower. In one aspect, the flexural modulus of the plastic material of body **12** can be approximately 6.0 GPa or lower. As yet another mechanical property, the tensile strength of the plastic material of body **12** can be approximately 100 MPa or lower as measured by ASTM D638 standards, approximately 90 MPa or lower, or approximately 80 MPa or lower. In one aspect, the tensile strength of the plastic material of body **12** can be less than approximately 75 MPa as measured by ASTM D638 standards.

Still referring to Figures 1 to 5, body **12** can comprise an upper surface **36**, a lower surface **38** and one or more lateral and exterior side walls. A sign or indicator can be disposed in at least one portion of upper surface **36** to indicate the polarity of the package. For example, a notch **N** can be disposed in an upper corner to indicate the cathode and/or anode side of LED package **10** and can also be useful in processing if desired. In one aspect, body **12** can comprise four lateral walls **40**, **41**, **42**, and **43**. Lateral walls **40-43** can comprise the same or different lengths. In one aspect, lateral walls can form a substantially square, rectangular, circular or any other suitably shaped package body **12** and corresponding footprint. For illustration purposes, a rectangular package **10** is illustrated wherein opposing lateral walls comprise substantially the same length. For example, first lateral wall **40** and opposing third lateral wall **42** can comprise substantially the same or similar length which can be longer than one or more adjacent lateral walls. Likewise, second lateral wall **41** and opposing fourth lateral wall **43** can comprise substantially the same or similar length which can be shorter than one or more adjacent lateral walls.

Second and fourth lateral walls **41** and **43**, respectively, can be disposed and adjacent first and third lateral walls **40** and **42**, respectively.

Body **12** can, as mentioned previously, further define reflector cavity **24**. Reflector cavity **24** can comprise substantially the same shape as lateral walls **40-43** or any other suitable shape. For example, reflector cavity **24** can comprise a substantially square, rectangular, circular, or any other suitably shaped cavity. For illustration purposes only and without limitation, reflector cavity **24** is shown as a substantially rectangular cavity having substantially curved corners **44** connecting one or more adjacent walls. Corners **44** could optionally comprise substantially squared corners or any other suitable shape. Reflector cavity **24** can comprise two opposing walls that can be longer in length than adjacent walls. Reflector cavity **24** can be defined at the upper surface **36** of body **12** and can extend to a cavity floor **46**. Reflector cavity can be disposed or inclined at an angle between the upper surface **36** and cavity floor **46**. Cavity floor **46** can be substantially flush with thermal and electrical elements, or can be at least partially disposed above and/or below such elements. Cavity floor **46** can comprise a portion of body **12** which can be configured in any suitable configuration to electrically and/or thermally isolate portions of the thermal and electrical elements. In one aspect, the thermal element can be fully electrically and/or thermally isolated from electrical elements. Specific dimensions of body **12** are illustrated and discussed with respect to Figure 7 below.

Referring to Figures 1-5, LED package **10** can comprise one or more electrical and thermal elements. Electrical elements can comprise electrical leads **18** and **20** which can further comprise integrally formed and extending, external portions **28** and **30**. The thermal element can comprise a heat transfer material **26** or a heat transferring substrate, such as for example a heat slug disposed on a bottom floor of reflector cavity **24** of package body **12**. Reflector cavity **24** can optionally be coated with a reflecting substance and/or filled to a desired level with an encapsulant **E**. In Figure 1, the dotted line illustrates a first level to which encapsulant **E** may be filled within reflector cavity **24**. That is, encapsulant **E** can be filled to a level substantially flush with the top of

reflector cavity **24**, or in the alternative it may be filled to any suitable level within reflector cavity **24** and can comprise a concave or convex surface and even exceed or extend above reflector cavity **24** as known in the art. Encapsulant **E** can comprise any suitable material known in the art and can optionally comprise a phosphor or a lumiphor to interact with light emitted by the LEDs **14** and responsively emit light of a different wavelength spectrum.

Heat transfer material **26** can comprise a single metal, an alloyed metal, and/or combinations or layers thereof. Heat transfer material **26** can comprise any suitable thermally conducting material known in the art. Heat transfer material **26** can be formed integrally as one piece or, in the alternative it can comprise several portions, for example a protruding portion **162** (Figure 12A) attached to and extending from a base portion of thermally conducting material assembled together as known in the art. Heat transfer material **26** can comprise any suitable type of heat transfer device. In one aspect, heat transfer material **26** can be an intermediary thermal structure for transferring heat to another structure such as a heat transfer layer or a heat sink of an external source (not shown) for further heat dissipation. External sources can comprise, for example, a PCB, metal-core printed circuit board (MCPCB), or other suitable source or substrate. In some aspects, external source can comprise a substrate of a backlighting system or other display panel system such as illustrated in Figures 14-16. In one aspect, heat transfer material **26** can comprise a thermal structure with limited heat capacity and capable of heating up quite quickly if not effectively connected thermally to a further heat transfer device such as an actual heat sink.

Wirebonding the LEDs **14** and ESD protection device **16** using one or more conducting wires **15** can electrically connect the LEDs **14** and ESD protection device **16** to electrical elements. In some aspects, LEDs **14** and ESD protection device **16** can be reverse wirebonded (Figure 11) for facilitating thinner packages and packages having shallower reflector cavity depths contributing to thinner packages. Heat transfer material **26** can be at least partially electrically and/or thermally isolated from electrical elements of the package. In one aspect, heat transfer material **26** can be fully electrically

and/or thermally isolated from metal leads **18** and **20** by one or more insulating portions **32** of body **12**. An exposed lower surface **34** of heat transfer material **26** can extend from the lower surface **38** of body **12**. Exposed lower surface **34** can be flush with lower surfaces of external portions of metal leads **28** and **30**. Heat transfer material **26** can conduct heat away from LEDs **14** and LED package **10** thereby allowing improved heat dissipation therefrom. In one aspect, the one or more LEDs **14** can be mounted on an optional submount (not shown) arranged between the LEDs and heat transfer material **26**.

Electrical elements can comprise first and second electrical leads **18** and **20** formed from a leadframe which can serve as anode and cathode connections supplying the LEDs **14** with current sufficient for illuminating the LEDs. In one aspect, electrical leads **18** and **20** can comprise a metal or any other suitable electrically conducting material known in the art. First electrical lead **18** can comprise one or more external portions **28** extending from body **12**. Second electrical lead **20** can comprise one or more external portions **30** extending from body **12** at opposing lateral sides, for example, second and fourth lateral sides **41** and **43**, respectively. Each of the external portions **28** and **30** can comprise mirror images or different configurations. For illustration purposes, external portions **28** and **30** are shown as mirror images. External portions **28** and **30** can comprise vertical portions **48** extending external the lateral sides of body **12**. In one aspect, external portions can extend from opposing lateral faces of the body outward from a center portion of the package. Each vertical portion **48** can extend from body **12** at a lateral exterior face and transition into a linear portion **50** which can extend below lower surface **38** of body **12** and turn in towards thermal element **26**. When external portions **28** and **30** are disposed on opposing sides, linear portions **50** can turn in towards and face each other. A first bend **52** can be disposed adjacent lateral side walls where external portions **28** and **30** first protrude from LED package **10**. Each vertical portion **48** can transition to form linear portion **50** at a second bend **54**. Second bends **54** can be disposed below vertical portion **48** and can perpendicularly transition the vertical portion **48** into the linear portion **50**. This configuration can be referred to as a "J-bend" type lead component.

Linear portion **50** can electrical connect with and external source when soldered or otherwise suitably connected. For illustration purposes the J-bend lead component is illustrated, however, any suitable configuration of lead components is contemplated herein. External portions **28** and **30** can be soldered or otherwise connected to an electrical current source and external heat sink to permit operation of the one or more LEDs **14**.

Referring to Figure 3, one or more recesses **R** can be defined in exterior side walls of the body **12** adjacent to (e.g., below) locations where the external portions of the leads **28** and **30** extend through the exterior side walls. Such recesses **R** can be disposed in lower portion **22B** of the body and can taper inwardly towards the heat transfer material **26** and below the first bends **52** in external portions **28** and **30** of the leads. Each recess **R** can have a depth relative to the corresponding exterior side wall, for example, lateral walls **41** and **43**, with the depth of each recess **R** preferably being at least as large as an average thickness of the electrical leads. Recesses **R** can provide multiple benefits. First, the recesses **R** can eliminate presence of material immediately disposed below the first bends **52** thereby reducing stress applied to the body **12** when the first bends **52** are formed after the leadframe **100** (Figure 8) is retained in the body **12**. Second, recesses **R** can enable each first bend **52** to have a tighter bending radius and reduce or eliminate outward extension of the bent portions **52** thereby reducing the effective footprint of LED package **10**. A smaller footprint can enable LED packages such as package **10** to be mounted at higher densities over an external substrate, for example a panel for a panel display system. LED packages **10** can optionally be overlaid with a Lambertian reflector or diffuser having reduced hole spacing (e.g., within a backlit display device, such as a LCD display), thereby enhancing lighting performance such as by enabling higher flux density and/or greater lighting uniformity.

Figure 3 further illustrates package thickness **T** as measured from upper surface **36** of LED package body **122** to a lower surface of linear portion **50** of the electrical leads. Package thickness **T** can have any suitable thickness. In one aspect, thickness **T** can be optimized and be a thin package, such as for example and without limitation, substantially equal to or less than 0.86 mm.

Thickness can be optimized by maintaining industry standard brightness levels and heat dissipation by retaining a somewhat thick heat transfer material **26**, for example a 0.5 mm thick heat transfer material, and optimizing the cavity space in which LED **14** can be disposed. For example, a depth of reflector cavity **24** can be reduced by using smaller chips and/or reverse wirebonding. The package thickness **T** dimension can at least partially have a thickness dimension of the reflector cavity **24** and the LED **14** thickness disposed therein. In addition, the package thickness **T** dimension can at least partially correspond to a measurement of the heat transfer material **26**.

Figure 4 illustrates a bottom view of LED package **10** and exposed lower surface **34** of heat transfer material **26**. Lower surface **38** of body **12** can comprise one or more recessed portions, generally designated **56** which can be disposed below external portions **28**, **30** of electrical leads **18** and **20**. Recessed portions **56** can allow overflow of attachment material, for example solder and/or flux, to move into recessed portion **56** when attaching LED package **10** to an external substrate, for example, a substrate used in backlighting and/or panel display systems. In some instances, at least a portion of body **12** can mold about at portion of heat transfer material **26**. For example, Figure 4 illustrates one or more corner portions **58** of the heat transfer area having body material molded or otherwise disposed over and/or adjacent heat transfer material **26**. External portions **28** and **30** of electrical leads **18** and **20**, respectively, can be disposed inboard of a corner of LED package **10**. For example, external portions **28** and **30** of electrical leads **18** and **20**, respectively, can comprise at least two external portions disposed on either side of a central axis **A** of package **10** and can extend inwardly towards heat transfer material **26** and towards each other. In one aspect, LED package **10** can comprise at least two external portions **28** and **30** extending per lateral side which can bend such that each external portion is disposed and extended over lower surface **38** of package and can be at least partially disposed in recessed portions **56**.

Figure 5 illustrates a cross-sectional view of LED package **10** along **5-5** of Figure 2 of LED package **10**. Figure 5 illustrates body **12** defining reflector

cavity **24**. Reflector cavity can comprise a cavity floor **46**. In one aspect, cavity floor **46** can be flush with an upper surface **60** of heat transfer material **26**. In one aspect, cavity floor **26** can be flush with first and second upper surfaces **62** and **64** of first and second electrical leads **18** and **20**, respectively. In one aspect, cavity floor **26** can be flush with each of upper surface **60** and upper surfaces **62** and **64**. As previously described, body **12** can comprise any suitable material known in the art, and can be formed about, thereby encasing thermal and electrical elements. Encapsulant **E** can be disposed to any suitable level within reflector cavity **24** and encapsulant **E** can optionally containing a phosphor or lumiphor. For illustration purposes encapsulant **E** is shown as substantially flush with an upper surface **36** of body **12** and the top of the reflector cavity **24**, but it can be filled to any level above or below the top of reflector cavity **24** and can comprise a convex or concave surface as may be desired.

Also illustrated in Figure 5 is heat transfer material **26** which can be disposed at least partially between electrical leads **18** and **20**. In other aspects, heat transfer material **26** can be disposed in any suitable configuration with respect to electrical leads **18** and **20**. Electrical leads **18** and **20** can be stamped and can have thinner members than heat transfer material **26**. In one aspect, heat transfer material **26** can have a thickness extending from cavity floor **46** and through the entire lower portion **22B** of LED package **10**. Heat transfer material **26** can extend through from the lower surface **38** of LED package **10** and can extend to a plane parallel with bottom surfaces of linear portions **50** of first and second electrical leads **18** and **20**, respectively. In one aspect, heat transfer material **26** can have a thickness of 0.5 millimeters (mm). In one aspect, the thickness **T** of the package can be 0.86 mm. Thus, heat transfer material **26** can be less than approximately 60% of the package thickness thereby maintaining good thermal management properties. In other aspects, heat transfer material **26** can be less than approximately 50% of the package thickness. Heat transfer material **26** can comprise at least one lateral protrusion **66** defined along a lateral wall. Lateral protrusion **66** can be disposed adjacent electrical elements, for example, adjacent first and second

electrical leads **18** and **20**, respectively. In one aspect, heat transfer material **26** can comprise opposing lateral protrusions **66** defined along opposing lateral walls such that the protrusions extend into body portion **12**. Lateral protrusions **66** can promote secure retention of heat transfer material **26** by body **12** and can also reduce the potential for leakage, for example of solder during manufacture of the LED package **10**, or of encapsulant **E** disposed in reflector cavity **24** during operation of LED package **10** along interfaces between the body **12** and the heat transfer material **24**. Such protrusions **66** along side walls of heat transfer material **24** may be varied in number, size, shape, and orientation (e.g. angled upward or downward, e.g., Figures 12A and 12B). Heat transfer material **26** can be at least partially, electrically and/or thermally isolated from first and second electrical leads **18** and **20**, respectively. For illustration purposes, Figure 5 shows heat transfer material **26** as fully electrically isolated and separated from first and second electrical leads **18** and **20** by one or more isolating portions **32** of body **12**.

Figure 5 further illustrates at least one set of opposing external portions **28** and **30** of first and second electrical leads **18** and **20**, respectively, as formed integrally with electrical leads **18** and **20** and extending from opposing lateral sides. External portions **28** can comprise first bends **52** which transition external portions **28** and **30** into vertical portions **48**. Vertical portions **48** can bend at second bend **54** and perpendicularly transform thereby forming linear portions **50**. Vertical portions **48** can extend downward along lower portion **22B** of body **12**. Opposing linear portions **50** of first and second metal leads **18** and **20** extend inwardly towards heat transfer material **26** and inwardly towards each other towards a center of LED package **10**.

Figures 6A and 6B illustrate different embodiments of LED package **10**. For example, Figure 6A illustrates a LED package, generally designated **70** which is similar in form and function to LED package **10**. LED package **70**, however, comprises at least two LEDs **14** mounted in parallel over heat transfer material **26**. That is, LED package **70** can comprise at least two LEDs **14** electrically connected in parallel. Each of the at least two LEDs **14** can electrically connect through one or more wirebonds **15** to each of the first and

second electrical leads **18** and **20**, respectively. In one aspect, the at least two LEDs **14** can comprise an array of LEDs **14** connected in parallel.

Figure 6B illustrates an LED package generally designated **80** comprising at least two LEDs **14** electrically connected in series. LED package **80** can be similar in form and function to LED package **10**. LED package **80**, however, can comprise at least two LEDs mounted in series over heat transfer material **26**. That is, LED package **80** can comprise at least two LEDs **14** wherein a first of the at least two LEDs is electrically connected to first electrical lead **18** and a second of the at least two LEDs **14** is electrically connected to second electrical lead **20**. The at least two LEDs **14** are then electrically connected to each other using electrically conductive wirebonds. When connecting LEDs **14** in series, it can be important to electrically connect the electrical terminal of a preceding LED to an opposite electrical terminal of a subsequent LED to ensure electrical current or signal will not be shorted in the series. In one aspect, the at least two LEDs **14** can comprise an array of LEDs connected in series.

Figure 7 illustrates a top view of an LED package generally designated **90**. LED package **90** is shown with one LED **14** schematically illustrated therein but there can be one or more LEDs **14**. LED package **90** can be any of packages **10**, **70**, or **80**. LED **14** can have a length designated **X** and a width designated **Y** which can be any suitable measurement such as according to the measurement data in Table 2 discussed further below. LED package **90** illustrates various dimensions of the package itself. For example, typical dimensions, for example, lengths, widths, thicknesses, and areas can be such as those illustrated in Figure 7 and disclosed in Table 1 below.

Table 1

Reference Character	Description of Dimension	Approx. Measurement Ranges (in mm)
L1	Overall package length, including portions of electrical leads	6 to 7
L2	Length of package body	5.7

L3	Length of reflector cavity measured at upper surface of body	5.4
L4	Length of cavity floor	3.47
L5	Length of upper surface of body disposed outside of reflector cavity	0.15
L6	Length of upper surface of heat transfer material	1.97
L7	Corner length	0.3
W1	Width of overall package body	2 to 3
W2	Width of reflector cavity measured at upper surface of body	2.7
W3	Width of cavity floor	1.7
*T	Overall thickness of package	0.86
* designates the thickness dimension as illustrated in Figures 3, 5 and 9		

Table 1 illustrates possible length and width dimensions for LED package **10**. In one aspect, the overall package area (L1 x W1) can be approximately 18 mm when calculated from a 6 mm x 3 mm package. In another aspect, overall package width can be 14 mm when calculated from an approximately 7 mm x 2 mm package. Any shape, dimension, and structure of LED chip such as LED **14** can be used in LED package **90**. As described earlier, more than one LED **14** can be disposed in LED package **90**. LED **14** can have various lengths and widths and are not limited to those as shown in Table 1, which are approximately (i) 300 μm x 300 μm, (ii) 500 μm x 500 μm, (iii) 520 μm x 700 μm, and (iv) 430 μm x 580 μm. Any suitable dimension of LED **14** can be used. Where thicker LEDs **14** are used, the thickness of overall package T can be approximately 0.97 mm or 1.08 mm or any suitable thickness depending on the thickness of the LEDs disposed in package.

LED package **90** can be provided in various lengths, widths, and in thicknesses with smaller LEDs, such as LED **14**, than LEDs in conventional

packages. For example and without limitation, Table 2 illustrates various sizes and ratios of dimensions for LED package **90.**

Table 2

Package Feature	Approx. Size of Package Feature (L x W (mm))	Approx. Size of LED (L x W (μm))	Ratio of LED to Package Feature	% of Package Feature Occupied by LED
Package Area (L1 x W1 in Figure 7)	6 x 3	520 x 700 (=364,000)	0.020	2.02
	6 x 3	500 x 500 (=250,000)	0.014	1.39
	6 x 3	430 x 580 (=249,500)	0.014	1.39
	6 x 3	300 x 300 (=90,000)	0.005	0.50
	7 x 2	520 x 700	0.026	2.60
	7 x 2	500 x 500	0.018	1.79
	7 x 2	430 x 580	0.018	1.78
	7 x 2	300 x 300	0.006	0.64
Cavity floor Area (L4 x W3 in Figure 7)	3.47 x 1.7	520 x 700	0.062	6.17
	3.47 x 1.7	500 x 500	0.042	4.24
	3.47 x 1.7	430 x 580	0.042	4.23
	3.47 x 1.7	300 x 300	0.015	1.53

Table 2 above illustrates for example and without limitation possible LED **14** to package ratios for different size packages. LED **14** can be a range between approximately 0.5 and 2 % of the overall package size in an approximately 6 x 3 mm package where at least one LED is disposed within the package. Ratio and percentage calculations in Table 2 are based on total chip area. That is, in Table 2, the column indicating an approximate size of the LED is the length and

width for one LED chip. If two or more LEDs are used in a package, the ratios could change. In one aspect, LED **14** can range less than approximately 5% of the overall package size. In other aspects, LED **14** can range less than approximately 3% of the overall package size. In other aspects, LED **14** can range less than approximately 2% of the overall package size. In other aspects, LED **14** can range less than 1% of the overall package size. In conventional packages similar in size to a 6 x 3 mm package, the LED such as LED **14** can typically average greater than approximately 2% of the overall package size.

An LED such as LED **14** in accordance with the subject matter herein can range between approximately 0.64% and 2.6% of the overall package size in an approximately 7 x 2 mm package where at least one LED **14** is disposed within the package. In one aspect, LED **14** can range less than approximately 5% of the overall package size. In other aspects, LED **14** can range less than approximately 3% of the overall package size. In other aspects, LED **14** can range less than approximately 2% of the overall package size. In other aspects, LED **14** can range less than 1% of the overall package size.

Similarly, for a rectangular cavity floor of approximately 3.47 x 1.7 mm, one LED **14** can range from between 1.53% to 6.17% of the area comprising the cavity floor. That is, in one aspect, LED **14** can be less than approximately 7% of the cavity floor. In a further aspect, LED **14** can be less than or equal to approximately 6.5% of the cavity floor. In other aspects, LED **14** can be less than approximately 5% of the cavity floor. In other aspects, LED **14** can be less than approximately 3% of the cavity floor. In other aspects, LED **14** can be less than approximately 2% of the cavity floor. In other aspects, LED **14** can be less than approximately 1% of the cavity floor. In other aspects, LED **14** can be less than approximately 0.5% of the cavity floor.

Figure 8 illustrates one embodiment of a leadframe, generally designated **100** which can be disposed, and in some aspects molded, within an LED package **10**. Leadframe **100** can comprise at least one thermal element and one or more electrical elements. Thermal element can comprise heat transfer material **26** and electrical elements can comprise first and second

electrical leads **18** and **20**, respectively. Figure 8 illustrates heat transfer material **26** disposed at least partially between first and second electrical leads **18** and **20**. Any suitable arrangement is contemplated. First and second electrical leads **18** and **20**, can extend outwardly from a proximal edge into one or more external portions **28** and **30**. For example, first electrical lead **18** can comprise a proximal edge **112** disposed adjacent to heat transfer material **26**. First electrical lead **18** can extend about a first aperture **114** thereby forming at least two external portions **28**. First electrical lead can extend about multiple apertures **114** thereby forming a plurality of external portions **28**. Each of external portions **28** can bend externally into a vertical portion perpendicular a linear portion as previously described, for example forming a J-bend configuration bending inwardly towards the lower surface of heat transfer material **26**. External portions **28** can comprise distal ends **116** distally located from heat transfer material **26** which can be sheared or otherwise separated from a sheet of metal comprising a plurality of leadframes **100**.

Similarly, second electrical lead **20** can comprise a proximal edge **118** disposed adjacent to heat transfer material **26**. Second electrical lead **20** can extend about a second aperture **120** thereby forming at least two external portions **30**. Second electrical lead could extend about multiple apertures **120** thereby forming a plurality of external portions **30**. Each of external portions **30** can bend externally into a vertical portion perpendicular a linear portion as previously described, such as forming a J-bend configuration bending inwardly towards the lower surface of heat transfer material **26**. Such bending of external portions **28** and/or **30** can be performed after forming of the body structure. External portions **30** can comprise distal ends **122** distally located from heat transfer material **26**. Heat transfer material **26** can comprise one or more terminating ends **124** which can be sheared or otherwise singulated from a sheet of leadframes **100**. Terminating ends **124** of heat transfer material **124** can be sheared substantially flush with lateral walls, for example, walls **40** and **42** of LED package **10**.

Still referring to Figure 8, each of first and second apertures **114** and **120** can provide multiple benefits. For example, at least a portion of first and

second apertures **114** and/or **120** can become at least partially filled with body material. This can promote secure retention of the first and second electrical leads **18** and **20** within the body **12**. In addition, each of first and second apertures **114** and **120**, respectively, can reduce the amount of lead material (e.g., metal) subject to being bent to form the first and second bends **52** and **54**, respectively. This can reduce the amount of bending force required to form the first and second bends **52** and **54** as is particularly desirable when the first and second bends are formed after molding, or otherwise positioning, the body **12** around the electrical leads **18** and **20**. Bending is preferably performed sufficiently to position external portions **28** and **30** of first and second electrical leads **18** and **20** at least partially within the recesses **56** of lower surface **38** of the body.

Figure 9 illustrates another embodiment of a cross-sectional view of an LED package generally designated **130**. Figure 9 can be similar in form and function as that shown in Figure 5, however, as illustrated thermal element may include a recessed surface disposed in a top surface of the heat transfer material, otherwise known as a down-set surface. Figure 9 illustrates body **12** defining reflector cavity **24**. Reflector cavity can comprise cavity floor **46** that can, in one aspect, can be flush with an upper surface of first and second upper surfaces **62** and **64** of first and second electrical leads **18** and **20**, respectively. In one aspect, cavity floor **46** can disposed above upper surface **60** and upper surfaces **62** and **64**. That is, the upper surface **60** of heat transfer material **26** can comprise a recess portion **132** that can be down-set from the cavity floor **46**. In one aspect, reflector cavity **24** can comprise a depth **D1** disposed between cavity floor **46** and upper surface **36** of body **12**. In one aspect for example, depth **D1** can be 0.36 mm. Depth of reflector cavity **24** can be less than a depth **D2** from the upper surface **36** of body **12** and the recess portion **122** of heat transfer material **26**. In one aspect, thickness of package from upper surface **36** of body **12** to the bottom of exterior portions of electrical leads **18** or **20** can be approximately equal to or less than 0.86 mm, and the thickness of the heat transfer material **26** which is not recessed can be 0.5 mm. Reflector cavity **24** of LED package **120** can be approximately 42% of the

overall thickness **T**. LED packages **10**, **70**, and **80** can also have a cavity depth of 0.36 and the same overall package thickness ratio. Conventional LED packages can be thicker and have cavity depths averaging greater than 0.36 mm. Thus, conventional packages disadvantageously have a very different ratio of cavity to overall thickness and have not been optimized to be as thin as possible while maintaining or exceeding brightness levels and thermal management properties.

Figures 10A and 10B illustrate schematic drawings of cavity angles of which LED packages, such as LED package **10** and other packages described herein can have. In one aspect, a cavity can comprise a cavity angle measured between walls of reflector cavity **24**. In one aspect, cavity angles of packages described herein can comprise less than 140°. For example, Figure 10A illustrates a portion of cavity floor **46** disposed between exterior lateral walls **41** and **43**. That is, Figure 10A illustrates the longer measurement **L4** of cavity floor **46**. In one aspect for example, the cavity angle **θ** between the walls of the reflector cavity **24** can be 139.1° where the thickness **T** of the overall package (Figures 3, 9) can be approximately 0.86 mm. In one aspect, cavity angle **θ** between the walls of the reflector cavity **24** can be at least approximately 135° or more. Where thicker LEDs are used, the overall thickness of the package can increase to approximately 0.97 or 1.08 mm. Thus, in one aspect, the cavity angle **θ** between the walls of the reflector cavity **24** can be at least approximately 128° or more, such as for example 128.1°, where the thickness **T** of the overall package is 0.97 mm. In one aspect, the cavity angle **θ** between the walls of the reflector cavity **24** can be at least approximately 118° or more where the thickness **T** of the overall package is for example 1.08 mm. The wider cavity angle of packages having thinner, optimized dimensions can allow the reflection level within the package to maintain or exceed the amount of reflected light thereby maintain or exceed current brightness standards.

Figure 10B illustrates a portion of cavity floor **46** disposed between exterior lateral walls **40** and **42**. That is, Figure 10A illustrates the shorter width measurement **W3** of cavity floor **46**. In one aspect, the cavity angle **φ** between the walls of the reflector cavity **24** can be 108.5° where the thickness **T** of the

overall package (Figures 3, 9) is approximately 0.86 mm. Where thicker LEDs are used, the overall thickness of the package can increase to approximately 0.97 mm or 1.08 mm. Thus, in one aspect, the cavity angle **φ** between the walls of the reflector cavity **24** can be 93.5° where the thickness **T** of the overall package is 0.97 mm. In one aspect, the cavity angle **φ** between the walls of the reflector cavity **24** can be 81.5° where the thickness **T** of the overall package is 1.08 mm.

Figure 11 illustrates a wirebonding method which LED packages, systems, and methods disclosed herein can advantageously incorporate. The wirebonding method can comprise a reverse ball-bonding technique. Figure 11 illustrates LED **14** mounted over heat transfer material **26**. As previously discussed, LED **14** can be directly attached to heat transfer material **26** or indirectly. That is, LED **14** can be attached to an intervening submount or substrate disposed between LED **14** and heat transfer material **26**. LED **14** can wirebond to each of electrical leads **18** and **20** for allowing electrical signal to pass between the electrical leads thereby illuminating LED **14**. Heat transfer material **26** can be electrically and/or thermally isolated from electrical leads by isolating portions **32** of the body disposed therebetween. A conventional wirebonding method is illustrated on the left hand portion of LED **14**, generally designated **140**. The conventional wirebonding method can begin by forming a ball **142** over a bondpad of LED **14**. A wire **144** extending from the ball connects ball **142** and stitches the wire to the first electrical element **18** forming a stitch **146**. As can be noted, the height of stitch **146** is less than the height of ball **142**.

A second wirebonding method is illustrated on the right hand portion of LED **14**, generally designated **148**. This method is termed reverse wirebonding which can be advantageous to use in thinner LED packages as the loop and ball height over the LED **14** can be reduced. Thus, cavity depth and package thicknesses can be reduced. In reverse wirebonding, a ball **150** can be formed on the electrical element **20** first. A wire **152** can extend from the ball **150** and form a stitch **154** on a bondpad of LED **14**. Notably, the loop and ball heights formed on the right hand portion **148** are lower than that of the left hand portion

140. This can be advantageous as smaller cavity depths can be used which can allow for thinner LED packages.

Figures 12A and 12B illustrate cross-sectional views of additional embodiments of heat transfer materials for LED packages described herein. As Figures 12A and 12B illustrate, lateral protrusions along the exterior edge of heat transfer material can comprise various configurations. For illustration purposes, only two additional embodiments of lateral protrusions are shown, however, any suitable configuration is contemplated. Figure 12A illustrates a first additional embodiment of heat transfer material, generally designated **160**. In this embodiment, heat transfer material **160** can comprise an upper surface **60**, a lower surface **34**, a lower protruding portion **162**, and curved lateral protrusions **66**. Curved lateral protrusions **66** can extend outward from lateral side walls **164** of heat transfer material **160**. Lower protrusion **162** can be formed integrally with heat transfer material **160** or it can comprise a separate portion affixed thereto using any suitable method. In one aspect, lower protrusion **162** can be advantageous to facilitate better wetting if solder is used to attach LED packages to external substrates. Better wetting can allow for less voids in the solder interface, and can result in a more reliable package.

Referring to Figure 12B, in another embodiment heat transfer material, generally designated **170** is illustrated. Heat transfer material **170** can comprise an upper surface **60**, a lower surface **34**, a lower protruding portion **172**, and upwardly-angled lateral protrusions **66** extending outward and upward from lateral side walls **174**. Downwardly-angled lateral protrusions can be employed in a similar embodiment (not shown). Any suitable configuration of the foregoing lateral protrusions may be employed. Lateral protrusions can be formed by any suitable manufacturing method, including but not limited to stamping, extruding, milling, machining, or any other suitable process. In further embodiments, lateral protrusions can be replaced with, or supplemented by, recesses (not shown) in lateral side walls of heat transfer material for providing similar sealing utility, with such recesses being formable by similar methods.

Figures 13A and 13B illustrate side views of a LED **14** as it may be positioned for mounting over substrate **180**. Substrate **180** can comprise any suitable metallic material and can comprise any substrate within an LED package, such as packages **10** (Figure 1) or any package described herein. For example, substrate **180** can comprise heat transfer material **26** or any layer otherwise deposited over thermal transfer material **26**. LED **14** can comprise any size, shape, dimension, and/or structure of, for example, a LED chip. Figure 13A illustrates an example of a metal-to-metal die attach. Figure 13B illustrates another example of a metal-to-metal die attach. Metal-to-metal die attach refers to attaching or bonding of one or more metals of the LED to substrate **180** disposed within an LED package. For example, the metals which can attach during metal-to-metal die attach techniques can comprise at least two of (i) a layer of metal on the backside of LED **14**, (ii) metallic substrate **180** within LED package **10** over which the LED will become mounted, and/or (iii) a metal assist material disposed between LED **14** and substrate **180**. Substrate **180** can comprise any suitable metal such as, but not limited to, silver (Ag) or platinum (Pt).

Figures 13A and 13B illustrate LED **14** comprising an upper surface **180** and a bonding surface **180**. LED **14** can comprise a horizontally structured device or a vertically structured device as previously described. Upper surface **182** of LED **14** can comprise one or more bondpads disposed thereon for wirebonding to electrical elements, for example, first and second electrical leads (Figure 1). In one aspect, LED **14** can comprise a vertically structured device wherein upper surface **182** can comprise a single bondpad. In another aspect, LED **14** can comprise a horizontally structured device wherein upper surface **182** can comprise two bondpads. In a further aspect, LED **14** can comprise a horizontally structured device wherein each of the p and n-sides electrically communicate with substrate **180** such that upper surface **182** does not require bondpads. Bonding surface **184** of LED **14** can comprise a portion of the p-side, n-side, or each of the p and n-sides of an LED device. In one aspect, the LED can be connected to substrate **180** at an insulating side of the LED device. In one aspect, the LED can be connected to a substrate **180** at a

portion of the growth substrate or carrier substrate of the LED as previously described.

Figures 13A and 13B illustrate bonding surface **184** of LED **14** as comprising a backside metal pad or bonding layer **186** for mounting over substrate **180**. Bonding layer **186** can extend the full length and/or surface area of bonding surface **184** or any suitable portion thereof. LED **14** can comprise lateral sides **188** which can extend between upper surface **182** and bonding surface **184**. Figures 13A and 13B illustrate inclined lateral sides **188**, however, lateral sides **188** can be substantially vertical or straight where a straight-cut LED is selected. Figure 13A illustrates upper surface **182** having a greater surface area than the surface area of bonding surface **184**. Figure 13B illustrates upper surface **182** having a smaller surface area than the surface area of bonding surface **184**. In some aspects, bonding surface **184** and upper surface **182** comprise the same surface area. As noted earlier, LEDs **14** can comprise a square, rectangle, or any suitable shaped LED in addition to having any suitable lateral side configuration.

Any suitable die attach method can be used to mount LED **14** within a LED package, for example, over substrate **180**. In one aspect, any suitable optimized die attach method and/or materials can be used. For example, optimized die attach methods can comprise metal-to-metal die attach methods for facilitating attachment of one or more metals on and/or between LED **14** and substrate **180**. Figure 13A illustrates an example of a metal-to-metal die attach method which can be eutectic or non-eutectic. This metal-to-metal die attach method can comprise using an attach material **190** to facilitate the metal-to-metal die attach. In one aspect, a flux-assisted eutectic metal-to-metal die attach method can be used and in other aspects a metal-assisted non-eutectic metal-to-metal die attach method can be used. In a flux-assisted eutectic, or flux eutectic, die attach method, bonding layer **186** can comprise a metal alloy having a eutectic temperature, for example, but not limited to, an alloy of gold (Au) and tin (Sn). For example, bonding layer **186** can comprise an 80/20 Au/Sn alloy having a eutectic temperature of approximately 280°C. In the flux eutectic technique, attach material **190** can comprise a flux material. In

the non-eutectic technique, attachment material **190** can comprise a metallic material. The flux material can serve as a conduit for facilitating the metal-to-metal die attach between the bonding layer **186** and substrate **180** when the bonding layer **186** is heated above the eutectic temperature. The metal of bonding layer **186** can flow into and attach to the metal of substrate **180**. The metal of bonding layer **186** or can atomically diffuse and bond with atoms of the underlying mounting substrate **180**. In one aspect, flux used in a flux-assisted eutectic method can comprise a composition, for example, 55-65% rosin and 25-35% polyglycol ether in addition to small amounts of other components. Any suitable flux material can be used however.

One consideration when choosing a material for use in flux-assisted eutectic die attach can be the melting point T_m of the solid state chip bonding layer **186**. A flux chosen for use can be liquid at room temperature or can require heating or melting to reach a melting point T_m. In one aspect, the body structure of a package in which an LED will be attached can comprise a plastic material having a melting point within approximately 28°C or less of the eutectic temperature of the bonding layer. In one aspect, at least one LED can be mounted over the substrate **180** at a mounting temperature of approximately 280°C or greater. Body **12** can comprise a plastic material with a melting point of approximately 28°C or less from the mounting temperature at which the at least one LED is mounted or attached. The melting point can be approximately 25°C or less from the mounting temperature at which the at least one LED is mounted or attached, approximately 20°C or less from the mounting temperature at which the at least one LED is mounted or attached, or even approximately 10°C or less from the mounting temperature at which the at least one LED is mounted or attached. Using flux-assisted eutectic die attach in such a package is unexpected based upon this small temperature difference and the possibility that the plastic may begin to be adversely affected during the die attach process.

Flux-assisted eutectic die attach methods can be tedious, and it is unexpected to use such methods when attaching LEDs within a molded plastic package body or for backlighting applications or situations. The flux eutectic die attach according to the present subject matter can utilize dispensing flux

assist material **190**, that can be liquid at room temperature, in an amount to be precisely the right volume to avoid either swimming of the LED chips or poor die attach if too much or too little flux is used. Flux-assisted eutectic die attach according to the present subject matter can also require the right composition for each of the flux assist material **190** and bonding metal **186** of the LED chips. Flux-assisted eutectic die attach according to the present subject matter can optimally utilize a very clean and flat surface and substrates that do not move or bend during heating and cooling such to stress the solder joint. Flux-assisted eutectic according to the present subject matter can utilize a fine surface roughness that is small enough not to encumber the Au/Sn bonding surface of the LED chips while being rough enough to allow flux to escape during heating. The heating profile can be matched perfectly to the bonding metal **186**, such as Au or AuSn, to ensure a good weld between the bonding metal **186** and underlying substrate **180**. Using flux-assisted eutectic for die attach according to the present subject matter also can utilize an inert atmosphere, such as a nitrogen atmosphere, to reduce oxygen gas (O_2) levels and also allow gravity to apply a downward force on the LED **15**. This can reduce the amount of oxidation at the metal-to-metal bond between bonding layer **186** and underlying substrate **180**.

Flux-assisted eutectic die attach can comprise several process techniques, for example, using a heated collet for dispensing the flux material **190**, heating the substrate and/or entire LED package, forming a gas, and applying pressure to the LED to the underlying mounting substrate. Methods can also comprise using a heated collet in combination with heating the mounting substrate and/or entire LED package and applying pressure. Body **12** can be heated quickly using microwave, laser, conduction and/or excitation fields, etc. all which can be done quickly and in an inert atmosphere allowing the body **12** to attain at least the eutectic temperature of the Au/Sn bonding metal on the LED (at least approximately 280°C). Heating thereby facilitates adequate metal-to-metal bonding between the bonding layer **186** of LED chips and underlying mounting substrate **180**. In one aspect, sonic scrubbing or thermo-sonic scrubbing techniques can also be used, as the friction of the scrubbing step can generate the heat required for metal-to-metal bonding. Flux-

assisted eutectic die attach methods can also comprise plasma cleaning in an inert atmosphere before and/or after flux eutectic die attach.

Still referring to Figure 13A, a non-eutectic metal-to-metal die attach method can be used which can also comprise an assist material **190**, the assist material **190** can comprise a metallic material. In this aspect, bonding layer **186** can comprise a single metal or a metal alloy. For example, bonding layer **186** can comprise Au, Sn, or AuSn. In non-eutectic methods, the bonding layer does not need to reach or exceed a temperature, for example, a eutectic temperature. In this aspect, assist material **190** can comprise a metallic material to facilitate the metal-to-metal bonding. For example, assist material **190** can comprise AuSn paste or Ag epoxy. Any suitable metallic assist material **190** can be used. The metal of bonding layer **186** can attach to the metal of the assist material **190**. The metal of the assist material **190** can also attach to the metal of substrate **180**. In one aspect, a metal "sandwich" forms between bonding layer **186**, assist material **190**, and substrate **180** in non-eutectic metal-to-metal attach techniques where a metallic assist material **190** is used. Metal-assisted, non-eutectic die attach can be tedious, just as flux-assisted methods, and it is also unexpected to use such methods when attaching LEDs within a molded plastic package body or for backlighting applications or situations. Metal-to-metal attachment using an assist material **190** can be hard to control and tedious when attaching multiple LEDs within a package having a plastic body. Heating the package to the appropriate temperature such that assist material **190** can facilitate metal-to-metal die attach can be hard to achieve in plastic packages, for example, packages comprising optimized plastic.

Figure 13B illustrates a metal-to-metal die attach technique which does not require an assist material **190**. One such method can comprise a thermal compression die attach method wherein the metal of bonding layer **186** will directly attach to the metal of substrate **180**. The thermal compression method can be eutectic or non-eutectic. In one aspect, thermal compression can be used when bonding layer **186** comprises an alloy having a eutectic temperature. In other aspects, bonding layer **186** can comprise a metal not

having a eutectic temperature. Substrate **180** can comprise any suitable metal, not limited to Ag or Pt. In one aspect, bonding layer **186** comprises any suitable metal. In one aspect, bonding layer **186** can comprise a layer of Sn having any suitable thickness. In one aspect, bonding layer **186** can comprise a thickness greater than approximately 0μm. In one aspect, bonding layer **186** can comprise a bonding layer equal to or greater than at least approximately 0.5 μm. In one aspect, bonding layer **186** can comprise a layer of Sn having a thickness of at least equal to or greater than approximately 2.0 μm. Unlike the flux-assisted eutectic or metal-assisted non-eutectic methods just described, thermal compression metal-to-metal die attach techniques can utilize an external downward force **F** as illustrated in Figure 13B. Force **F** can comprise a compression delivered in a heated environment, thus deemed a thermal compression, as opposed to dispensing a flux or metallic assist material **190**. The thermal compression technique is an alternative die attach method developed to reduce metal squeeze out of the bonding layer **190** which can form Shottky or Shunt defects and allow subsequent leakage of current and other various and related problems. In one aspect, the bonding temperature in thermal compression techniques can be approximately 255-265°C after subjecting substrate **180** to a pre-heat treatment or process. The substrate can be heated to a mounting temperature of at least 20°C above the melting temperature of the bonding layer **186**. The bonding time can be approximately 300 msec and the bonding force can be approximately 50 +/- 10 grams (g). Predetermined settings can be important for this method, including adequate preheat, bonding temperature, bonding time, and bonding force. The equipment and predetermined settings for use with thermal compression methods can be difficult to use and/or maintain, and it is unexpected to use such methods when attaching LEDs within a molded plastic package body or for backlighting applications or situations.

Although metal-to-metal methods have previously been used in solid state device packages comprising ceramic substrates and package bodies (in non-backlighting situations), it is not known and is unexpected to use flux-assisted eutectic, metal-assisted non-eutectic, or thermal compression die attach techniques for device packages having molded plastic bodies. It is also

not known and is unexpected to use flux-assisted eutectic, metal-assisted non-eutectic, and/or thermal compression attach techniques in LED backlighting situations as described further herein. It is also quite unexpected to use flux-assisted, metal-assisted, or thermal compression die attach techniques with molded plastic body **12** having optimized plastic material that can have, for example, a T_m of approximately 307°C. Light packages having LEDs utilizing metal-to-metal die attach methods as described herein can, for example and without limitation, offer light output of up to 122 lumens at 300 mA in cool white (CW), and up to 100 lumens at 300 mA in warm white (WW) color points. For example, LED packages disclosed herein can be used in lighting fixtures offering a minimum CRI for CW color points of 65 CRI. LED packages disclosed herein can be used in lighting fixtures offering a minimum CRI for CW color points of 75 CRI which corresponds to a range of 5,000 K to 8,300 K CCT. LED packages disclosed herein can also offer, for example, a minimum CRI for WW color points of 80 CRI which corresponds to a range of 2,600K to 3,700K CCT. Such LED packages described herein can be used for backlighting applications targeting backlighting color points and for both standard and high voltage configurations.

Packages disclosed herein can have longer L70 lifetime values than conventional packages by combining features such as, but not limited to, using optimized plastic and/or metal-to-metal die attach methods and materials in accordance herewith. The metal-to-metal die attach method can for example comprise one of the flux-assisted eutectic, metal-assisted non-eutectic, or thermal compression methods described in Figures 13A and 13B. It is believed that LED packages in accordance with the subject matter herein will be the first LED packages for backlighting to be ENERGY STAR® compliant and therefore meet the standards for energy efficiency set by the US Environmental Protection Agency (EPA). ENERGY STAR® products are those meeting the energy efficiency requirements set forth in ENERGY STAR® product specifications, the entire contents of which are hereby incorporated by reference herein.

Figure 14 illustrates an expanded perspective view of a representative flat display panel system, generally designated **200** in which LED packages

described herein can be utilized. Embodiments described and illustrated herein can provide uniform backlighting for small or large area display panels greater or less than a dimension of 17" diagonal. Display panel system **200** can be combined with other electrical and/or mechanical elements to provide computer monitors, televisions, and/or other flat display panels. As used herein, "uniform" backlighting means than an ordinary viewer who views the display at a conventional viewing distance is not aware of any discrepancy or variation in backlighting intensity. In some embodiments, variations of less than about 25% can provide uniform intensity, whereas, in other embodiments variations of less than 5% can provide uniform intensity. Display panel system **200** can comprise square, rectangle, or any suitable shaped panels of any suitable dimension. Embodiments of display panels described herein can provide direct backlighting of flat panel LCDs.

Figure 14 illustrates display panel system **200** comprising an illumination panel **202** and a display panel, or LCD panel **204**. Illumination panel **202** can comprise a plurality of LED packages or LEDs **206**. In one aspect, illumination panel **202** can comprise a planar (i.e., two dimensional) array of LEDs **206** mounted either directly over illumination panel **202** or arranged in packages over illumination panel **202**. LEDs **206** can be spaced apart from one another at a predetermined distance, or pitch **P** so as to provide substantially uniform backlighting of LCD panel **204**. LEDs **206** can be packed in a random array, a grid array (as shown), a staggered array, or any suitable array. Uniform and/or non-uniform packing may be provided. Pitch **P** between adjacent LEDs **206** can allow for uniform backlighting of at least a portion of LCD panel **204**. In one aspect, LEDs **206** can provide uniform backlighting over the entire LCD panel **204**. A frame (not shown) can be disposed about illumination panel **202** and LCD panel **204** to hold the panels adjacent and either together or spaced apart with one or more gaps disposed therebetween.

LCD panel **204** can comprise a flat display panel having planar array of LCD devices, or cells. In one aspect, LCD panel **204** can comprise a planar array of liquid crystal devices arranged into a matrix of pixels (not shown). An image can form on a front display surface **208** of LCD panel **204** when the

liquid crystal devices are subjected to backlight illumination. To provide backlight illumination to LCD panel **204**, the planar array of LEDs **206** comprising illumination panel **202** can be arranged into a matrix such that each LED **206** is arranged to provide illumination to a single LCD device or to a plurality of LCD devices thereby collectively defining specific images on display surface **208**. Backlight LEDs **206** can be arranged to illuminate the entirety or a portion of LCD panel **204**, the illumination passing through LCD panel **204** from a back surface **210** of the panel through the LCD pixels to the front surface **208** of the display panel. LCD panel **204** can comprise the back surface **210** parallel and opposing front surface **208** and a thickness disposed therebetween defined by the LCD devices, or cells. The thickness of LCD panel **204** can be any suitable dimension.

Optionally, one or more optical layers **212** may be disposed between illumination panel **202** and LCD panel **204**. Optical layer **212** can comprise at least one layer or film such as polarizing films, light scattering films, light guide films or any suitable film capable of manipulating light emitted by illumination panel **202**. In one aspect, optical layer **212** can comprise a diffuser that distributes light uniformly behind the viewing area. In one aspect, optical efficiency may be enhanced by direct backlighting such that the need for diffusing and/or optical films between illumination panel **202** and LCD panel **204** may be reduced or eliminated. In one aspect, optical layer can comprise an edge **511** along which one or more LEDs **206** may direct light. Optionally, the light could be directed along an edge of LCD panel as described in Figure 15B.

Figures 15A and 15B illustrate different cross-sectional views of an unexpanded display panel **200** described and illustrated by Figure 14. For illustration purposes, the figures illustrate LEDs **206** directing light toward optical layer **212**, however, the LEDs **206** in each of Figures 15A and 15B could direct light toward LCD panel **204** instead. That is, in Figure 15A optical layer **212** could be excluded, and in Figure 15B, optical layer **212** could be replaced with LCD panel **204**. The figures could otherwise be the same.

Figure 15A illustrates one or more LEDs **206** mounted over illumination panel **202** providing direct backlighting to LCD panel **204**. LEDs **206** can be disposed adjacent each other spaced apart a pitch **P** in rows, columns, and/or a random array (Figure 14). Pitch **P** can be the same dimension for LEDs **206** spaced apart between the rows and columns of the planar array, or the LEDs can be spaced apart in rows at a first pitch and spaced apart in columns at a second pitch. Alternatively, any suitable pitch **P** and variations of pitch can be used between the planar array of LEDs **206**. Figure 15A illustrates at least one optical film or layer **212** disposed between illumination panel **202** and LCD panel **204**, however, such film is optional. LEDs **206** can provide backlighting directly to LCD panel **204**. In one aspect, the planar array of LEDs **206** can be configured to transmit light directly to the planar array of LCD pixels comprising LCD panel **204** over a space, or gap, generally designated **214**. Gap **214** can be disposed between illumination panel **202** and LCD panel **204**, or optical layer **212**, and can define a space across which one or more individual light paths **216** can extend from the one or more LED devices **206**. In one aspect, light paths **216** can extend perpendicular to the planar array of LEDs **206** and perpendicular to LCD panel **204**. In other aspects, lights paths **216** can extend from an edge parallel LCD panel **204** or be reflected perpendicular LCD panel **204**. That is, in some aspects, at least some of the LEDs **206** can be disposed within a periphery of the LCD panel **204**.

Still referring to Figure 15A and in one aspect, each LED device **206** comprising the planar array of LEDs can emit light at an illumination angle **α** that can conform to desired radiation patterns. The edges of adjacent light paths **216** can just meet at a periphery **218**, or slightly overlap depending on pitch **P** at which adjacent LEDs **206** are spaced. When one or more LEDs **206** are spaced at pitch **P** shown, adjacent light paths **216** can intersect, or touch, at periphery edges **218**. If spaced closer together, individual light paths **216** can overlap. Different grids or arrangements of planar arrays of LEDs **206** can also affect the overlap and distribution of light paths **216**. In one aspect, light paths **216** can intersect at periphery edges **218** and/or overlap to provide uniform backlighting illumination to LCD panel **204**. Figure 15A illustrates at least one

column of the planar array of LEDs **206**. Light paths **216** from respective LEDs **206** in adjacent columns and/or rows can intersect and/or overlap. LEDs **206** can also be configured for indirect backlighting of LCD panel **204**, for example, LEDs **206** can be disposed around edges of illumination panel and indirectly reflect and illuminate LCD panel **204**.

Figure 15A further illustrates illumination panel **202** comprising a first surface **220** over which the one or more LEDs **206** can mount. Illumination panel **202** can comprise a second surface **222** parallel and opposing first surface **220**. First surface **220** of illumination panel **202** can face optical layer **212**. In one aspect, first surface **220** of illumination panel **202** can face back surface **210** of LCD panel **204**. Illumination panel **202** can comprise any suitable substrate over or onto which LEDs **206** may be mounted. For example, LCD panel **202** can comprise a circuit, PCB, MCPCB, or any other suitable substrate. First surface **220** of illumination panel **202** can comprise an electrically and/or thermally conductive surface. In one aspect, first surface **220** can comprise a metallic surface over which the one or more LEDs **206** can mount. In another aspect, top surface **520** can comprise a planar array of metallic surfaces over which the planar array of LEDs **206** can mount. One or more conductive traces (not shown) can connect the planar array of metallic surfaces such that electrical current or signal can flow to each of LEDs **206**.

Figure 15B illustrates another embodiment of panel display system **200**. In this system, the arrows indicate light being directed from the one or more LEDs **206** toward opposing side edges **211** of optical layer **212**. Optionally, the light can be directed toward an edge of LCD panel **204**. This embodiment comprises an edge lighting panel display system where the one or more LEDs direct light towards edges, rather than directly behind, the panels of panel display system **200**. LEDs **206** can be arranged in any suitable manner, such as in an array, and can be in any suitable LED package or outside of a package. LEDs **206** can be connected to a structure that can be positioned directly against and in contact with side edges **211** or can be spaced apart from side edges **211**. As shown in Figure 15B, LEDs **206** are shown spaced apart for illustration purposes only.

Figure 16 illustrates one embodiment of an illumination panel used in a LED backlighting system according to the subject matter herein. As previously discussed, LEDs attached within LED packages described herein can comprise a robust metal-to-metal die attach such as, but not limited to, flux eutectic, non-eutectic, and thermal compression die attach. Figure 16 illustrates one or more LED packages **230** attached over illumination panel **202**. LED package **230** can comprise any LED package described herein. For example, LED package **230** can be similar in form and function to LED package **10** previously described. Illumination panel **202** can comprise a fully integrated, solid electrically and thermally conductive panel, or in the alternative it can comprise one or more layers. In one aspect, illumination panel **202** can comprise a MCPCB having an electrically conductive layer **232** to which LEDs packages **230** can mount. One or more electrically insulating but thermally conductive layers **234** can be disposed adjacent and under electrically conductive layer **232**. In one aspect, thermally conductive layer **234** comprises a dielectric layer. A core layer **236** can be disposed adjacent and under thermally conductive layer **234**. In one aspect, core layer **236** can comprise a metal core substantially formed wholly of aluminum or copper.

As Figure 16 illustrates one or more LEDs **206** can be arranged in LED packages **230** over illumination panel **202**. At least one LED can be arranged within the package, however, more than one LEDs can also be mounted therein. In one aspect, emitter packages **230** can comprise a body structure **238** formed using optimized plastic materials previously described. In another aspect, emitter packages **230** can comprise a body **238** formed using any suitable plastic, non-plastic, silicone, or ceramic material. Packages can comprise a reflector cavity **242** as illustrated in Figure 16 having encapsulant **E** disposed therein, the encapsulant filled to any suitable level within package **230**. LEDs **206** can be attached within packages **230** using assisted eutectic or non-eutectic die attach methods, or thermal compression methods described herein. Assisted methods can comprise flux-assisted eutectic die attach and metal-assisted non-eutectic die attach methods. Encapsulant **E** can be dispensed or otherwise placed in a package **230** to an amount even with the

body structure, or to an amount such that a concave or convex surface forms. Encapsulant **E** can comprise one or more phosphors for emitting light of a desired wavelength.

LEDs **206** for use in backlighting or other panel display systems can comprise an arrangement or planar arrays of red, green, and blue LED devices configured to emit light that appears as a pixel of white light in operation. Sizes of red, green, and blue LEDs can be selected to meet a desired brightness and/or intensity balancing level. Any configuration of the red, green, and blue LEDs can be used. LED packages and/or LEDs utilizing metal-to-metal die attach methods as described herein can be used in backlighting systems and any suitable display panel system **200**. For example and without limitation, LED packages and/or LEDs used in backlighting and display panel systems can offer light output of up to 122 lumens at 300 mA in cool white (CW), and up to 100 lumens at 300 mA in warm white (WW) color points. For example, LED packages and/or LEDs disclosed herein can be used in lighting fixtures comprising fixtures used in display panel systems offering a minimum CRI for CW color points of 65 CRI. LED packages and/or LEDs disclosed herein can be used in lighting fixtures comprising fixtures used in display panel systems offering a minimum CRI for CW color points of 75 CRI which corresponds to a range of 5,000 K to 8,300 K CCT. LED packages and/or LEDs disclosed herein for use in display panel systems can also offer, for example, a minimum CRI for WW color points of 80 CRI which corresponds to a range of 2,600K to 3,700K CCT. Such LED packages and/or LEDs can be used for both standard and high voltage configurations.

Embodiments of the present disclosure shown in the drawings and described above are exemplary of numerous embodiments that can be made within the scope of the appended claims. It is contemplated that the configurations of thinner LED packages having higher brightness and reduced footprints and methods of making the same can comprise numerous configurations other than those specifically disclosed herein.

CLAIMS

What is claimed is:

1. A light emitting device package, the package comprising:

a package body comprising a package area;

at least one light emitting diode (LED) disposed within the package body; and

wherein the at least one LED occupies an area approximately equal to 2 percent (%) or less of the package area.

2. The package of claim 1, wherein the package body comprises a package thickness of approximately 0.86 millimeters (mm).

3. The package of claim 1, wherein the package body comprises a cavity depth of approximately 0.36 millimeters (mm).

4. The package of claim 1, wherein the package comprises an electrically isolated heat transfer material.

5. The package of claim 4, wherein the heat transfer material comprises a thickness of approximately 0.5 millimeters (mm).

6. The package of claim 1, wherein the package comprises a cavity floor, and the at least one LED occupies an area less than or equal to approximately 6.5% of an area of the cavity floor.

7. The package of claim 1, wherein the package body comprises a package length of approximately 6 millimeters (mm) and a package width of approximately 3 millimeters (mm).

8. The package of claim 1, wherein the package body comprises a package length of approximately 7 millimeters (mm) and a package width of approximately 2 millimeters (mm).

9. The package of claim 1, wherein the at least one LED comprises a length of less than approximately 550 micrometers (μm).

10. The package of claim 1, wherein the at least one LED comprises a width of less than approximately 700 micrometers (μm).

11. The package of claim 1, wherein the at least one LED comprises a length of approximately 520 micrometers (μm) and a width of approximately 700 micrometers (μm).

12. The package of claim 1, wherein the at least one LED comprises a length of approximately 500 micrometers (μm) and a width of approximately 500 micrometers (μm).

13. The package of claim 1, wherein the at least one LED comprises a length of approximately 430 micrometers (μm) and a width of approximately 580 micrometers (μm).

14. The package of claim 1, wherein the package body comprises an upper surface disposed outside of a reflector cavity, the upper surface comprising a length of approximately 0.15 millimeters (mm).

15. The package of claim 1, wherein the at least one LED is mounted in the package body using flux-eutectic, non-eutectic, or thermal compression die attach.

16. The package of claim 1, wherein the package body comprises plastic.

17. The package of claim 1, wherein the package comprises two LEDs.

18. The package of claim 17, wherein the two LEDs are electrically connected in series.

19. The package of claim 17, wherein the two LEDs are electrically connected in parallel.

20. The package of claim 1, wherein the cavity comprises a cavity angle of approximately 135° or more.

21. The package of claim 1, wherein the cavity comprises a cavity angle of approximately 128° or more.

22. The package of claim 1, wherein the cavity comprises a cavity angle of approximately 118° or more.

23. The package of claim 1, wherein the package is ENERGY STAR® compliant.

24. A light emitting device package, the package comprising:

a package body comprising a cavity disposed between an upper surface of the package body and a cavity floor, the cavity floor comprising an area;

at least one light emitting diode (LED) disposed within the package body; and

wherein the at least one LED occupies an area less than or equal to approximately 6.5 percent (%) of the area of the cavity floor.

25. The package of claim 24, wherein the package body comprises a package thickness of approximately 0.86 millimeters (mm).

26. The package of claim 24, wherein the cavity depth of approximately 0.36 millimeters (mm).

27. The package of claim 24, wherein the package comprises an electrically isolated heat transfer material.

28. The package of claim 24, wherein the heat transfer material comprises a thickness of approximately 0.5 millimeters (mm).

29. The package of claim 24, wherein the package body comprises a package length of approximately 6 mm and a package width of approximately 3 millimeters (mm).

30. The package of claim 24, wherein the package body comprises a package length of approximately 7 millimeters (mm) and a package width of approximately 2 millimeters (mm).

31. The package of claim 24, wherein the at least one LED comprises a length of less than approximately 550 micrometers (μm).

32. The package of claim 24, wherein the at least one LED comprises a width of less than approximately 700 micrometers (μm).

33. The package of claim 24, wherein the at least one LED comprises a length of approximately 520 micrometers (μm) and a width of approximately 700 micrometers (μm).

34. The package of claim 24, wherein the at least one LED comprises a length of approximately 500 micrometers (μm) and a width of approximately 500 micrometers (μm).

35. The package of claim 24, wherein the at least one LED comprises a length of approximately 430 micrometers (μm) and a width of approximately 580 micrometers (μm).

36. The package of claim 24, wherein the package body comprises an upper surface disposed outside of a reflector cavity, the upper surface comprising a length of approximately 0.15 millimeters (mm).

37. The package of claim 24, wherein the at least one LED is mounted in the package body using flux-eutectic, non-eutectic, or thermal compression die attach.

38. The package of claim 24, wherein the at least one LED is mounted in the package body using flux-eutectic, non-eutectic, or thermal compression die attach.

39. The package of claim 24, wherein the package body comprises plastic.

40. The package of claim 24, wherein the package comprises two LEDs.

41. The package of claim 40, wherein the two LEDs are electrically connected in series.

42. The package of claim 40, wherein the two LEDs are electrically connected in parallel.

43. The package of claim 24, wherein the cavity comprises a cavity angle of approximately 135° or more.

44. The package of claim 24, wherein the cavity comprises a cavity angle of approximately 128° or more.

45. The package of claim 24, wherein the cavity comprises a cavity angle of approximately 118° or more.

46. The package of claim 24, wherein the package is ENERGY STAR® compliant.

47. A light emitting device package, the package comprising:
a package body comprising a cavity;

a heat transfer material electrically isolated from at least one electrical element;

at least one light emitting diode (LED) disposed over the heat transfer material; and

wherein the cavity comprises a cavity depth of less than approximately 0.36 millimeters (mm) and a cavity angle of approximately 135° or more.

48. The light emitting device package of claim 47, wherein the package comprises a package thickness of less than approximately 0.9 millimeters (mm).

49. The light emitting device package of claim 47, wherein the package is disposed in a panel display system.

50. The light emitting device package of claim 47, wherein the package is disposed in backlighting panel display systems.

51. The light emitting device package of claim 47, wherein the package body comprises plastic.

52. The light emitting device package of claim 47, wherein the package length comprises at least approximately 6 millimeters (mm) and the package width comprises at least approximately 3 millimeters (mm).

53. The light emitting device package of claim 47, wherein the package length comprises at least approximately 7 millimeters (mm) and the package width comprises at least approximately 2 millimeters (mm).

54. A light emitting device package, the package comprising:

a package body comprising a package length and a package width, where the package length is different from the package width;

at least one light emitting diode (LED) disposed in the package body; and

wherein the package body comprises a package thickness of less than approximately 0.89 millimeters (mm).

55. The light emitting device package of claim 54, wherein the package thickness comprises approximately 0.86 millimeters (mm).

56. The light emitting device package of claim 54, wherein the package is ENERGY STAR® compliant.

57. A display panel system comprising:

a panel;

at least one light emitting diode (LED) package for providing light to the panel, the at least one LED package comprising:

a body comprising a package length and a package width, where the package length is different from the package width;

at least one light emitting diode (LED) disposed in the body; and

wherein the package body comprises a package thickness of less than approximately 0.89 millimeters (mm).

58. The display system of claim 57, wherein the LED package directly backlights the panel.

59. The display panel system of claim 57, wherein the LED package is configured to illuminate the side edge of the panel.

60. The display panel system of claim 57, wherein the system is ENERGY STAR® compliant.

61. A display panel system comprising:

a panel;

at least one light emitting diode (LED) package for providing light to the panel, the at least one LED package comprising:

a package body comprising a package area;

at least one light emitting diode (LED) disposed within the package body; and

wherein the at least one LED occupies an area approximately equal to 2 percent (%) or less of the package area.

62. The display panel system of claim 61, wherein the system is ENERGY STAR® compliant.

63. A method of fabricating a light emitting device package, the method comprising:

providing a package body comprising a package area;

providing at least one light emitting diode (LED); and

disposing the at least one LED within the package body where the at least one LED occupies an area approximately equal to 2 percent (%) or less of the package area.

64. The method of claim 63, wherein the package body comprises a package thickness of approximately 0.86 millimeters (mm).

65. The method of claim 63, wherein the package body comprises a cavity having a depth of approximately 0.36 millimeters (mm).

66. The method of claim 63, wherein the package comprises an electrically isolated heat transfer material.

67. The method of claim 63, wherein the heat transfer material comprises a thickness of approximately 0.5 millimeters (mm).

68. The method of claim 63, wherein the package comprises a cavity floor, and the at least one LED occupies an area less than or equal to approximately 6.5% of an area of the cavity floor.

69. The method of claim 63, wherein the package body comprises a package length of approximately 6 millimeters (mm) and a package width of approximately 3 millimeters (mm).

70. The method of claim 63, wherein the package body comprises a package length of approximately 7 millimeters (mm) and a package width of approximately 2 millimeters (mm).

71. The method of claim 63, wherein the at least one LED comprises a length of less than approximately 550 micrometers (μm).

72. The method of claim 63, wherein the at least one LED comprises a width of less than approximately 700 micrometers (μm).

73. The method of claim 63, wherein the at least one LED comprises a length of approximately 520 micrometers (μm) and a width of approximately 700 micrometers (μm).

74. The method of claim 63, wherein the at least one LED comprises a length of approximately 500 micrometers (μm) and a width of approximately 500 micrometers (μm).

75. The method of claim 63, wherein the at least one LED comprises a length of approximately 430 micrometers (μm) and a width of approximately 580 micrometers (μm).

76. The method of claim 63, wherein the package body comprises an upper surface disposed outside of a reflector cavity, the upper surface comprising a length of approximately 0.15 millimeters (mm).

77. The method of claim 63, wherein the at least one LED is mounted in the package body using flux-eutectic, non-eutectic, or thermal compression die attach.

78. The method of claim 63, wherein the package body comprises plastic.

79. The method of claim 63, wherein the package comprises two LEDs.

80. The method of claim 79, wherein the two LEDs are electrically connected in series.

81. The method of claim 79, wherein the two LEDs are electrically connected in parallel.

82. The method of claim 60, wherein the cavity comprises a cavity angle of approximately 135° or more.

83. The method of claim 63, wherein the cavity comprises a cavity angle of approximately 128° or more.

84. The method of claim 63, wherein the cavity comprises a cavity angle of approximately 118° or more.

85. The method of claim 63, wherein the light emitting device package is ENERGY STAR® compliant.

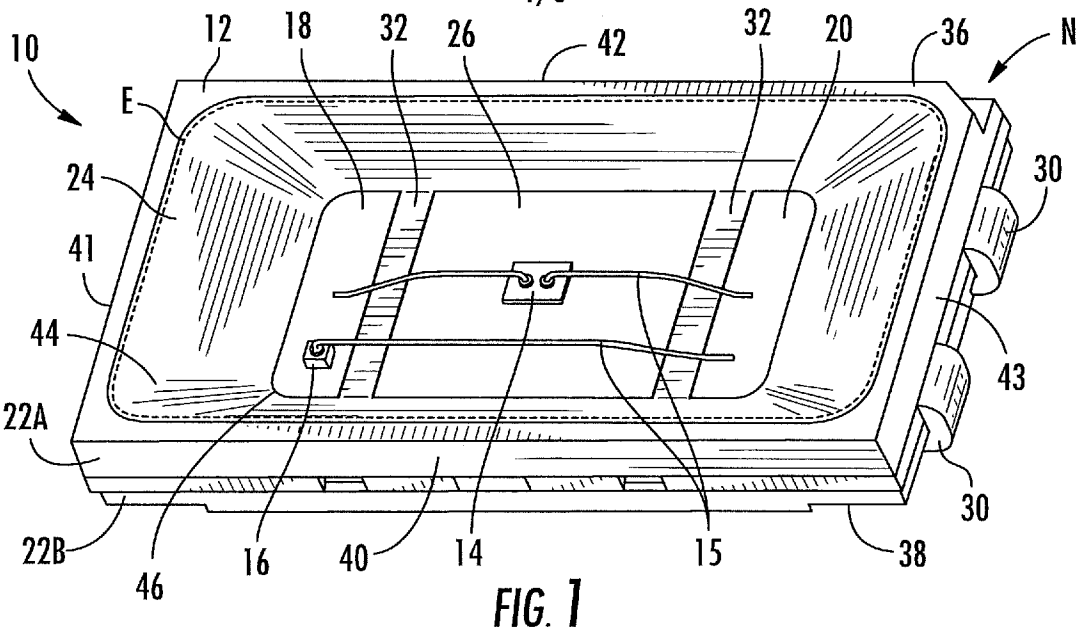


FIG. 1

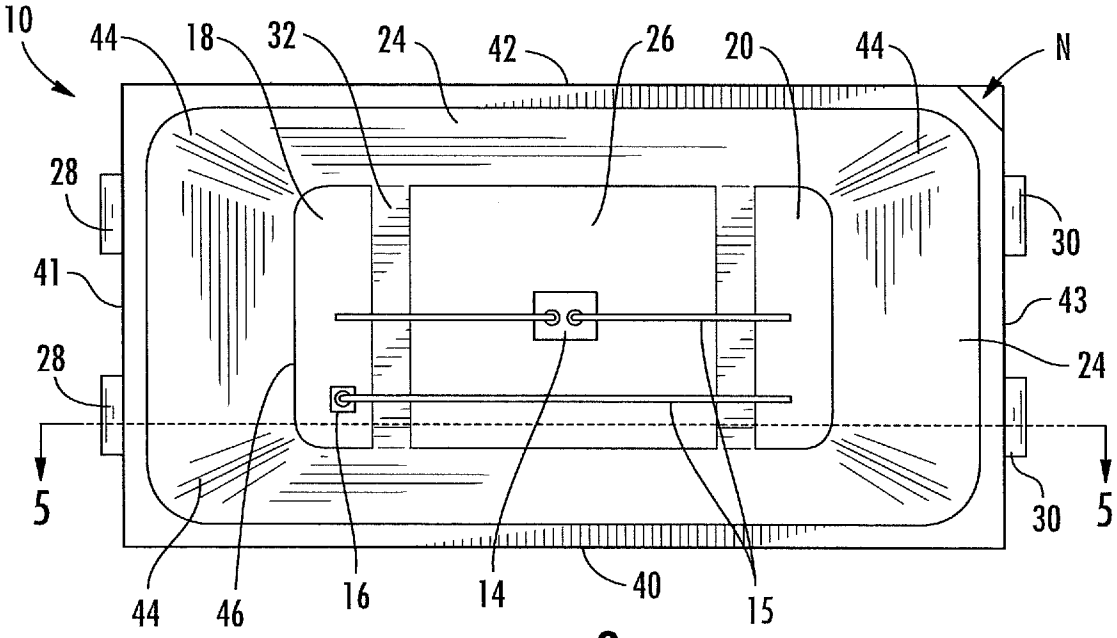


FIG. 2

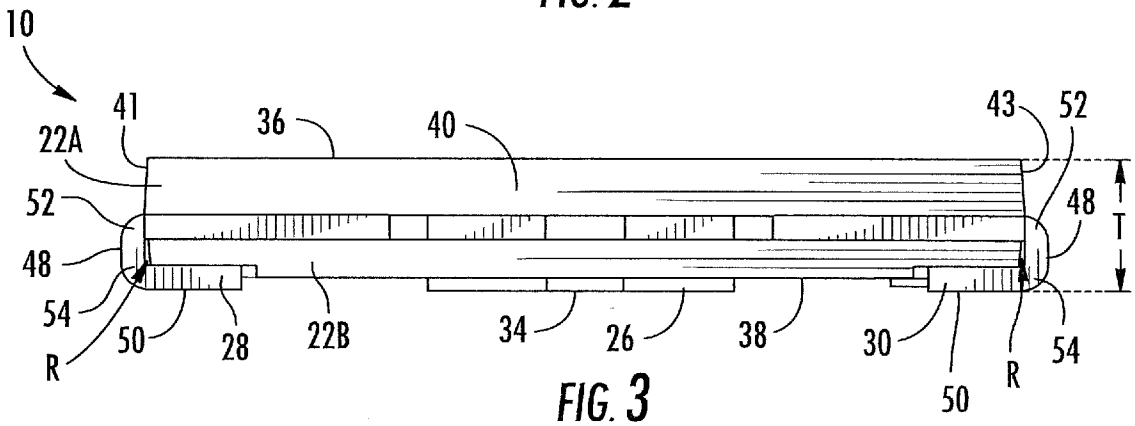


FIG. 3

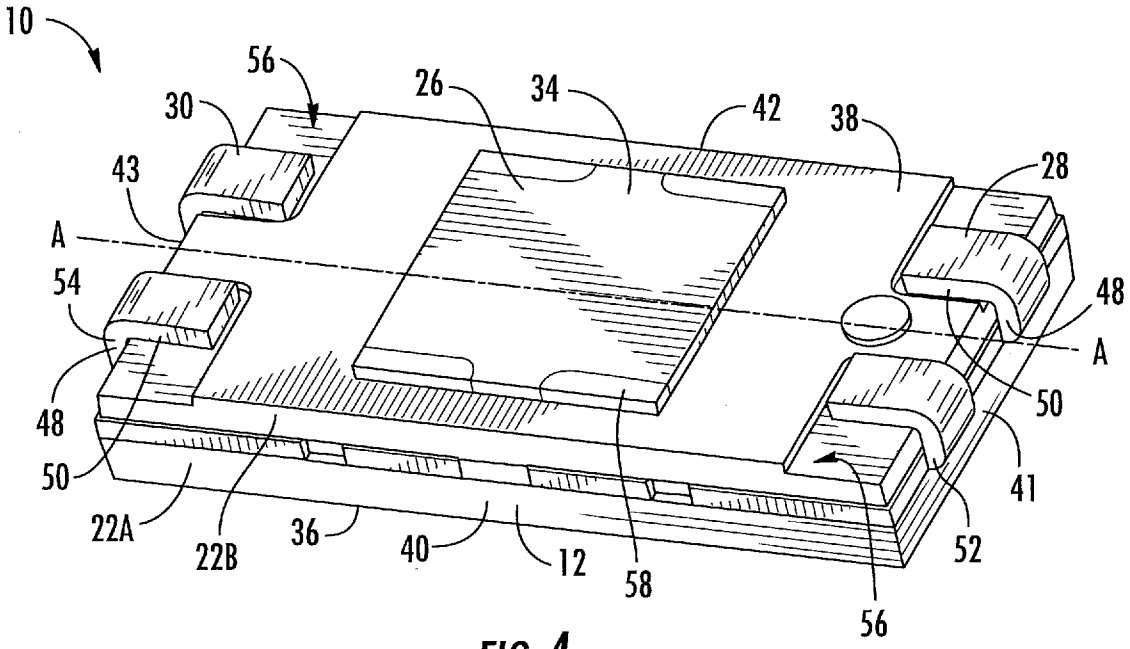

10
56
30
26
34
42
38
28
43
A
54
48
A
48
50
50
22A
22B
36
40
12
58
41
52
56

FIG. 4

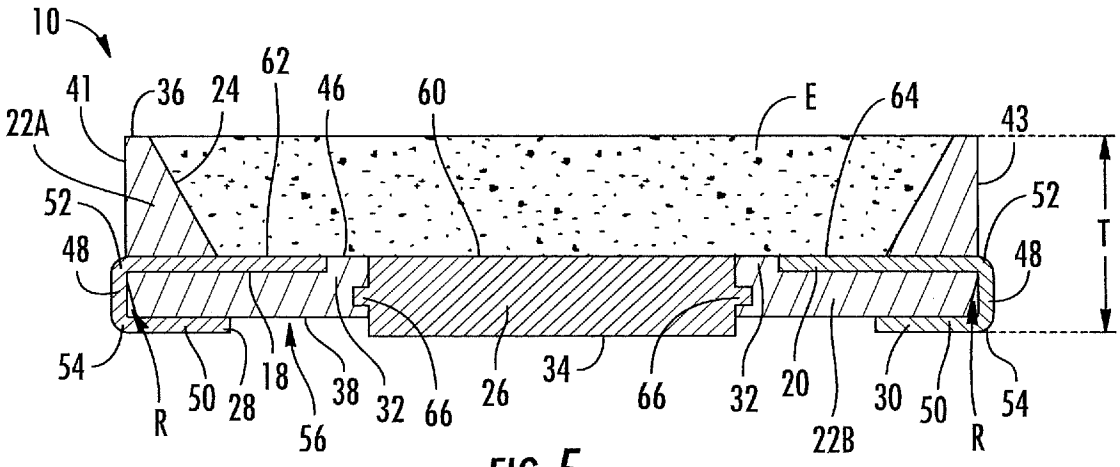

10
41
36
24
62
46
60
E
64
43
22A
52
52
48
48
T
54
R
50
28
18
56
38
32
66
26
34
66
32
20
22B
30
50
R
54

FIG. 5

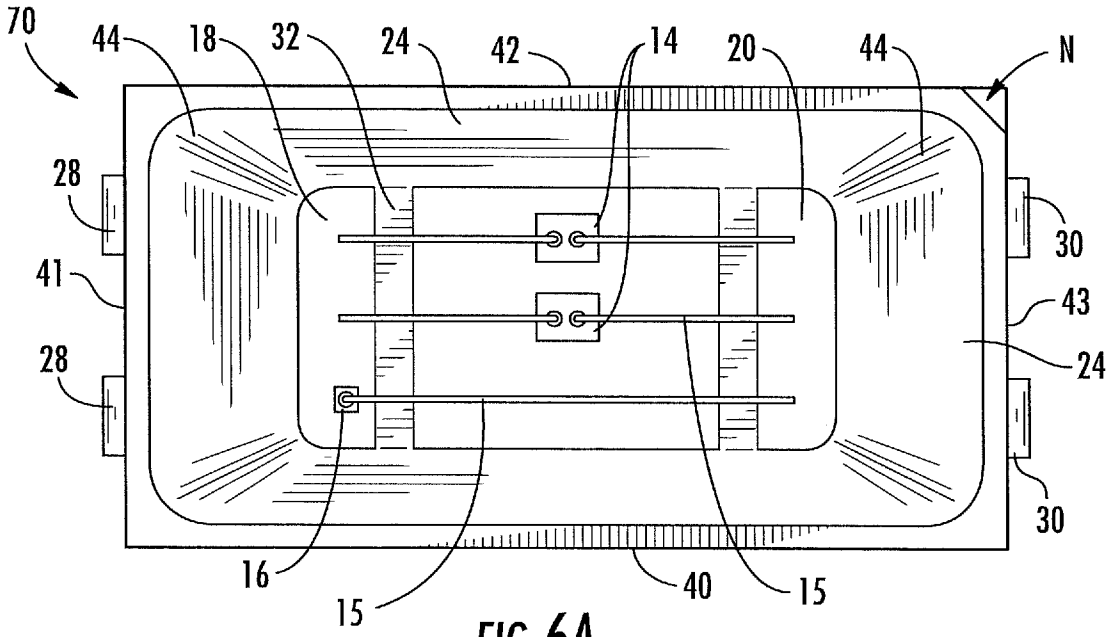

70
44
18
32
24
42
14
20
44
N
28
41
28
30
43
24
30
16
15
40
15

FIG. 6A

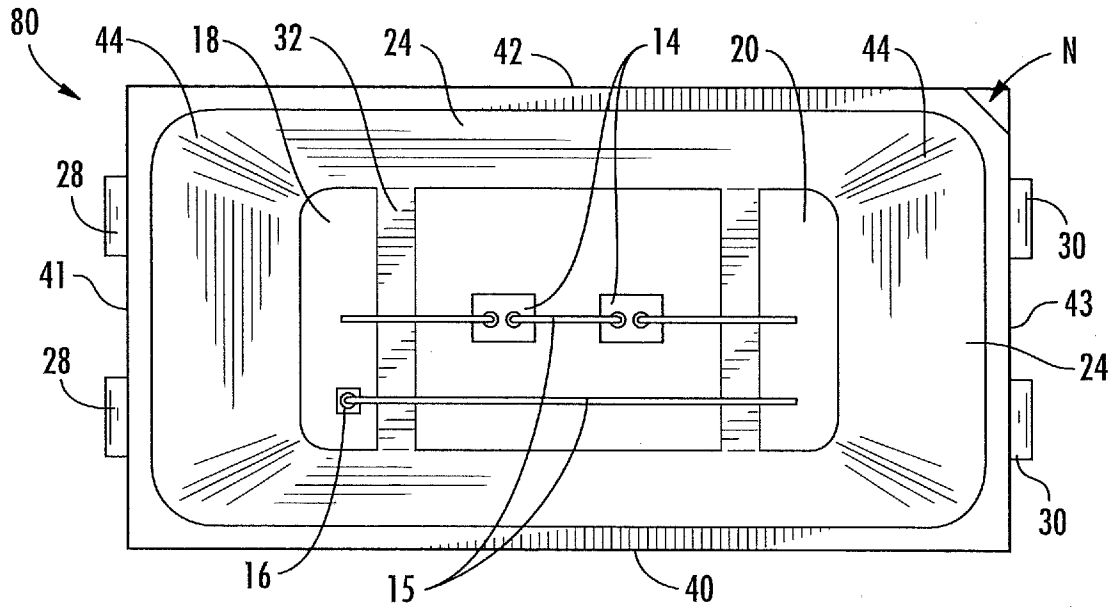

80
44
18
32
24
42
14
20
44
N
28
41
28
30
43
24
30
16
15
40

FIG. 6B

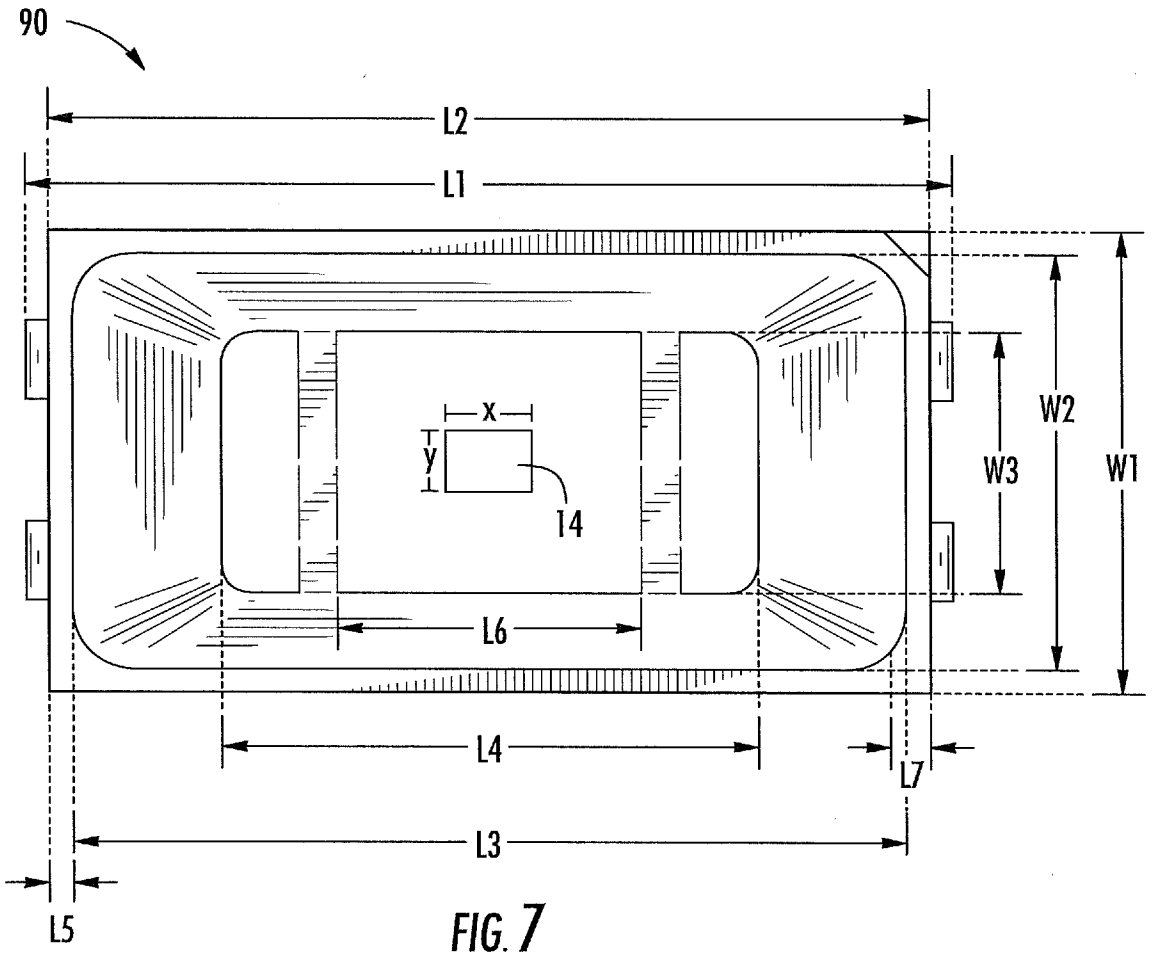

90
L2
L1
x
y
14
W2
W3
W1
L6
L4
L7
L3
L5

FIG. 7

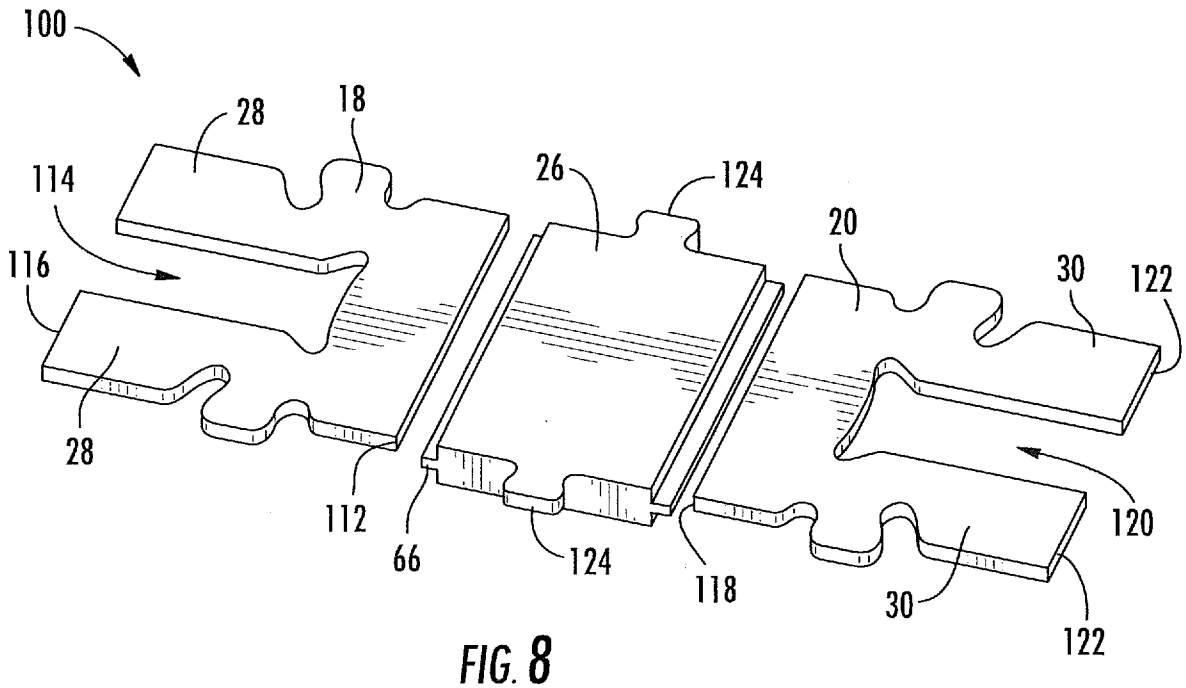

100
28
18
114
26
124
20
116
30
122
28
112
66
124
118
120
30
122

FIG. 8

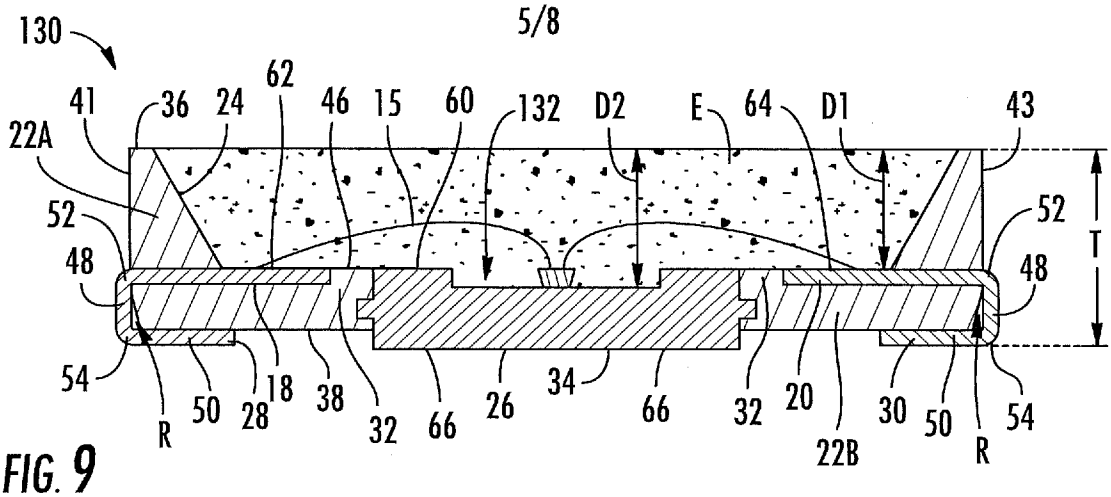


FIG. 9

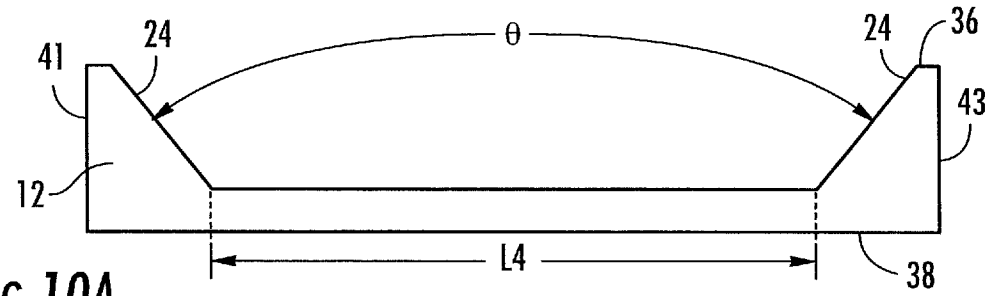


FIG. 10A

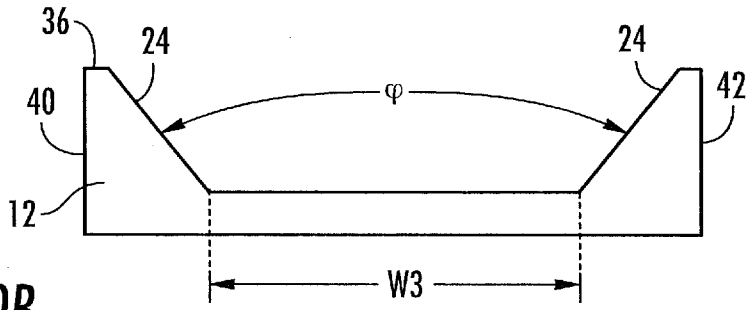


FIG. 10B

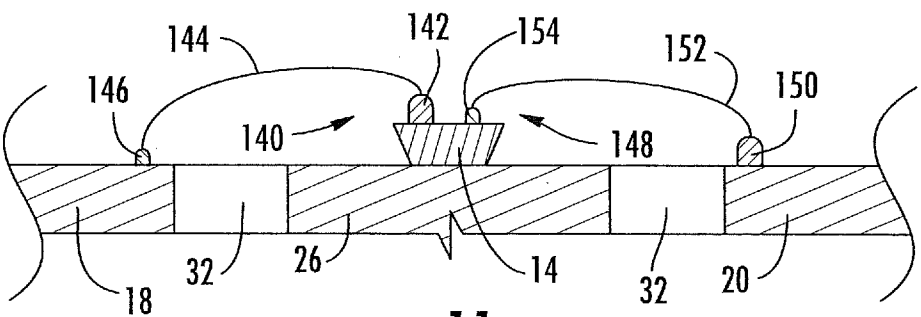


FIG. 11

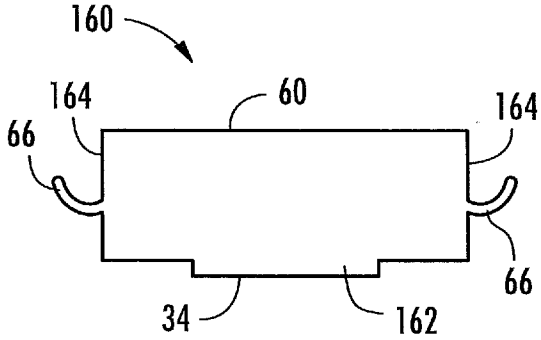


FIG. 12A

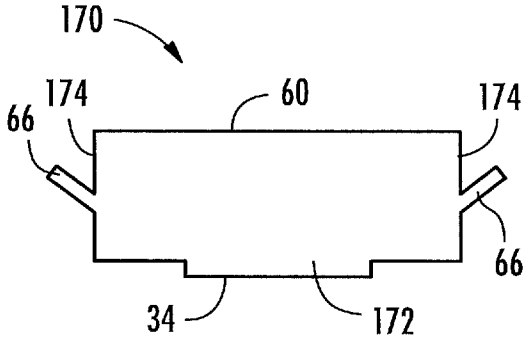


FIG. 12B

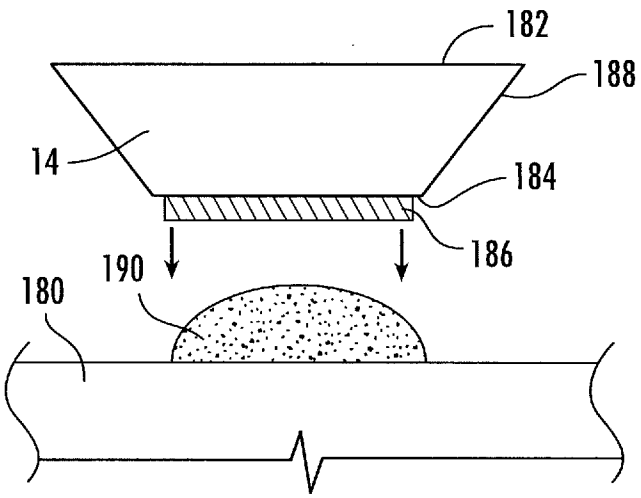


FIG. 13A

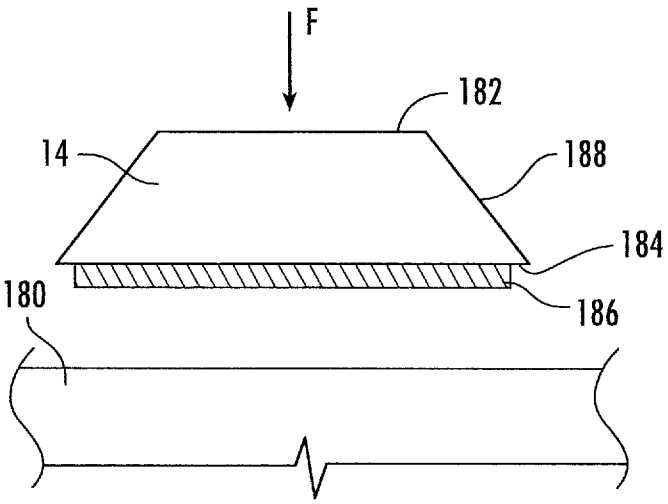


FIG. 13B

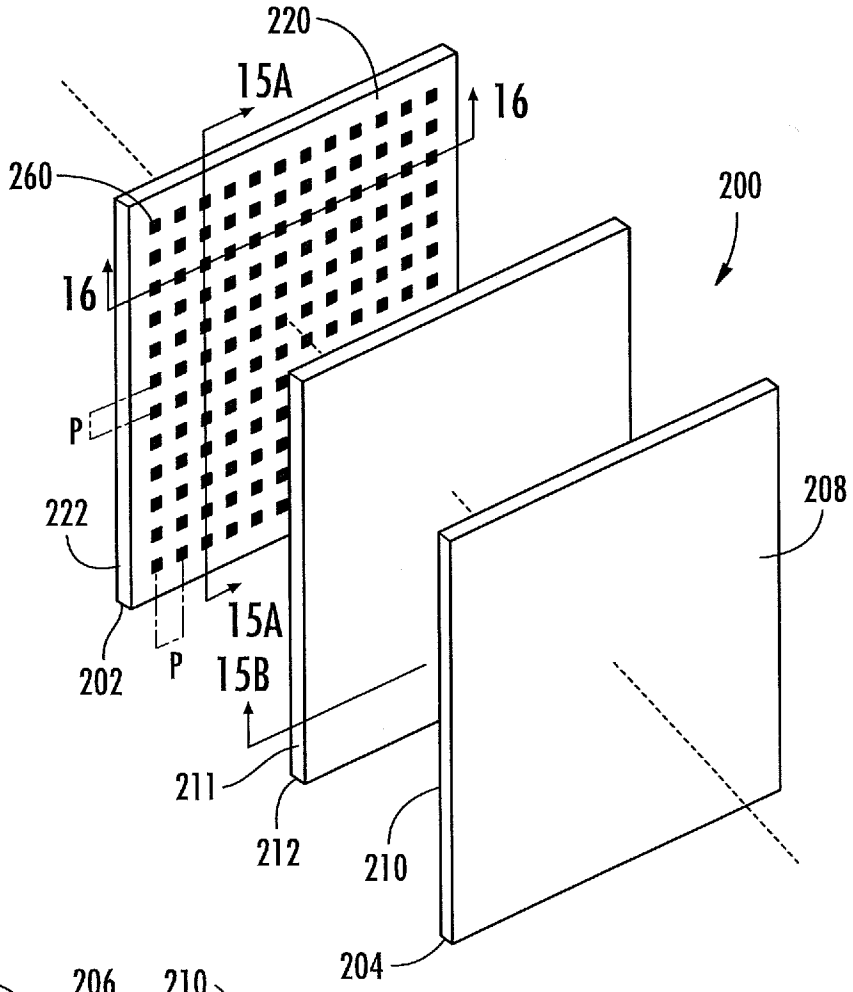


FIG. 14

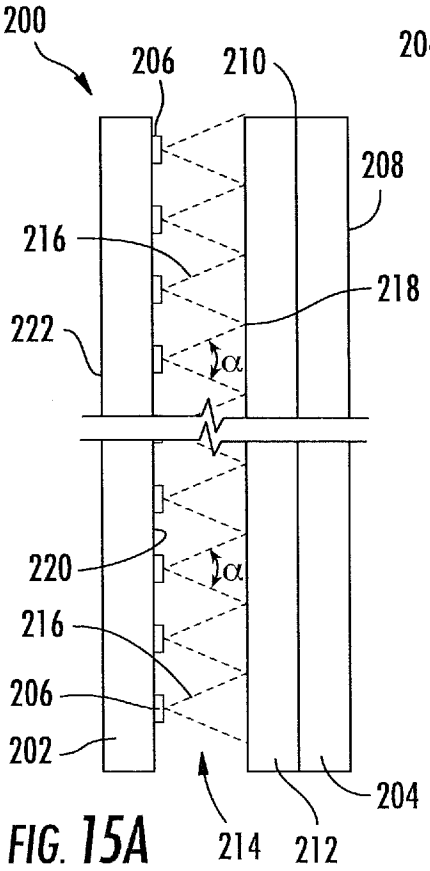


FIG. 15A

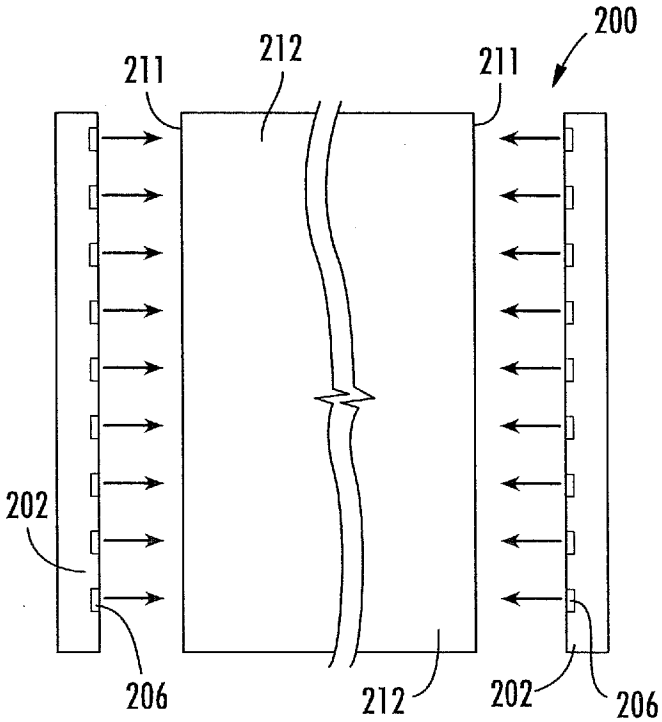


FIG. 15B

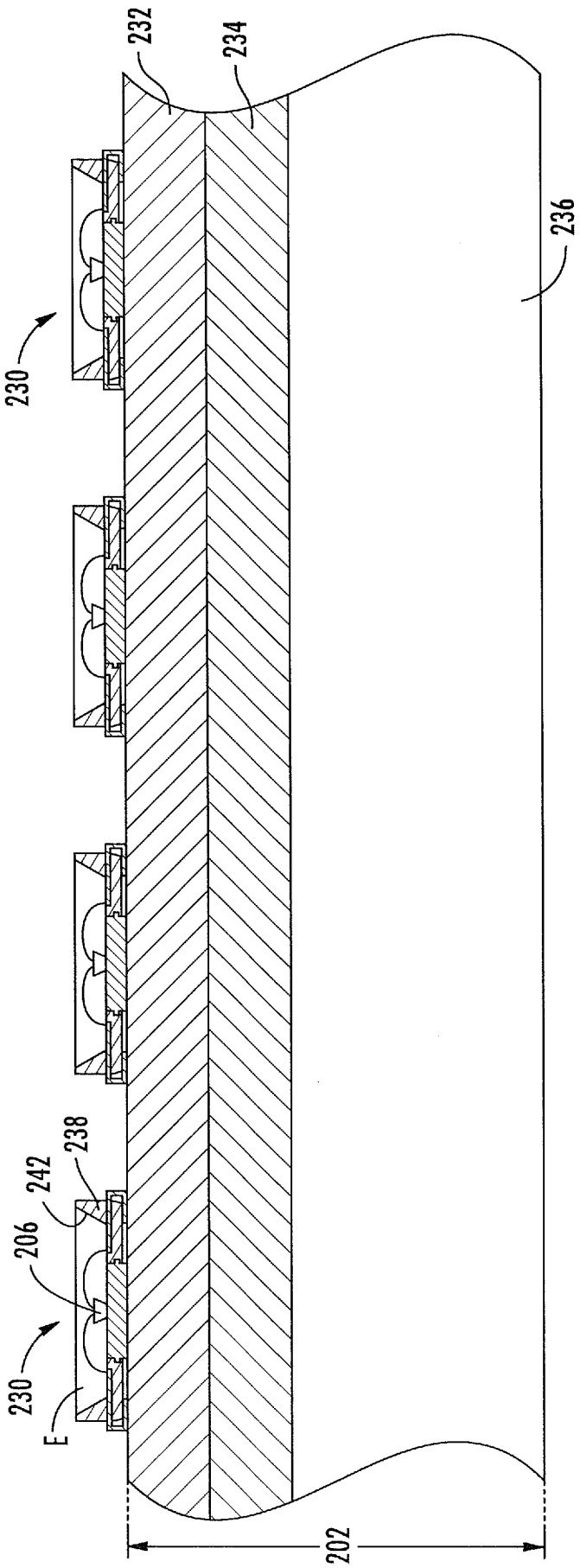


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/023285

A. CLASSIFICATION OF SUBJECT MATTER

H01L 33/48(2010.01)i

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)

H01L 33/00-H01L 33/64; H01L 21/50; H01L 29/06

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:package, area, thickness, length, width

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010-0102345 A1 (SUNG MIN KONG et al.) 29 April 2010 See paragraphs [0041]-[0051]; claims 1,8,10; and figures 4-9	1-85
A	US 2006-0118808 A1 (SADAMU ISHIDU et al.) 08 June 2006 See abstarct; paragraphs [0014],[0034]; and figures 4,7	1-85
A	US 2009-0321779 A1 (CHANG WOOK KIM et al.) 31 December 2009 See abstarct; claim 1; and figures 6,9	1-85
A	US 2007-0114514 A1 (SHIN ITO) 24 May 2007 See abstarct and figures 1,5	1-85
A	US 2010-0133554 A1 (CHRISTOPHER P. HUSSELL) 03 June 2010 See paragraphs [0040]-[0042] and figure 8	1-85

☐ 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 JUNE 2012 (26.06.2012)	**27 JUNE 2012 (27.06.2012)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer PARK, Hye Lyun Telephone No. 82-42-481-8362

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/023285

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0102345 A1	29.04.2010	JP 2010-525569 A	22.07.2010
		JP 2010-525569 T	22.07.2010
		KR 10-0901618 B1	08.06.2009
		KR 10-2008-0094177 A	23.10.2008
		US 2011-0133240 A1	09.06.2011
		US 2011-0220952 A1	15.09.2011
		US 7858993 B2	28.12.2010
		US 8022415 B2	20.09.2011
		US 8101956 B2	24.01.2012
		WO 2008-130140 A1	30.10.2008
US 2006-0118808 A1	08.06.2006	CN 1748327 A	15.03.2006
		CN 1748327 C0	17.09.2008
		EP 1605523 A1	14.12.2005
		JP 2007-142479 A	07.06.2007
		JP 4001169 B2	31.10.2007
		KR 10-1007164 B1	12.01.2011
		KR 10-2005-0106399 A	09.11.2005
		US 2008-0067540 A1	20.03.2008
		US 2008-0105894 A1	08.05.2008
		US 7335925 B2	26.02.2008
		US 7420223 B2	02.09.2008
		US 7504671 B2	17.03.2009
		WO 2004-082034 A1	23.09.2004
US 2009-0321779 A1	31.12.2009	CN 101621110 A	06.01.2010
		CN 101621110 B	24.08.2011
		CN 1971954 A	30.05.2007
		CN 1971954 C0	30.05.2007
		EP 1791190 A1	30.05.2007
		EP 2112698 A1	28.10.2009
		EP 2315265 A1	27.04.2011
		JP 2007-150315 A	14.06.2007
		JP 2009-239321 A	15.10.2009
		KR 10-0780176 B1	27.11.2007
		KR 10-0910479 B1	04.08.2009
		KR 10-2007-0055361 A	30.05.2007
		KR 10-2007-0097393 A	04.10.2007
		US 2007-0120234 A1	31.05.2007
		US 2009-0283792 A1	19.11.2009
US 2007-0114514 A1	24.05.2007	CN 1971956 A	30.05.2007
		CN 1971956 B	11.05.2011
		CN 1971956 C0	30.05.2007
		JP 2007-142289 A	07.06.2007
		JP 2007-142290 A	07.06.2007
		US 7943946 B2	17.05.2011
US 2010-0133554 A1	03.06.2010	KR 10-2012-0015362 A	21.02.2012

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/023285

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2011-0031865 A1	10.02.2011
		US 2011-180827 A1	28.07.2011
		US 7923739 B2	12.04.2011
		WO 2010-141215 A2	09.12.2010
		WO 2010-141215 A3	03.03.2011
		WO 2010-141215 A3	09.12.2010