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(54) POWER SURFACE MOUNT LIGHT EMITTING DIE PACKAGE

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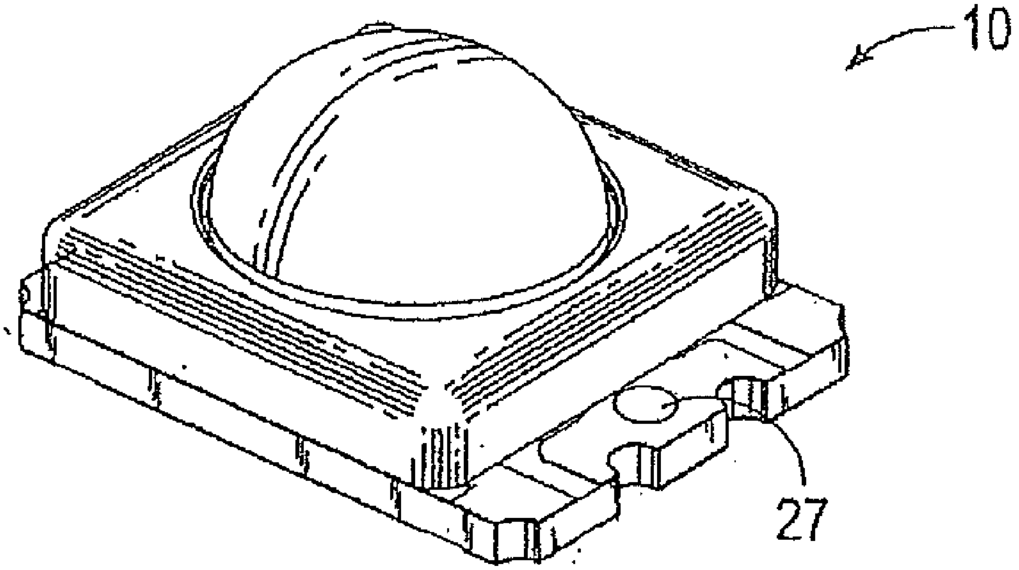
CPC ***H01L 33/60*** (2013.01); ***H01L 33/64*** (2013.01); ***H01L 33/52*** (2013.01)
USPC **257/98**

(57) ABSTRACT

A light emitting die package is provided which includes a metal substrate having a first surface and a first conductive lead on the first surface. The first conductive lead is insulated from the substrate by an insulating film. The first conductive lead forms a mounting pad for mounting a light emitting device. The package includes a metal lead electrically connected to the first conductive lead and extending away from the first surface.



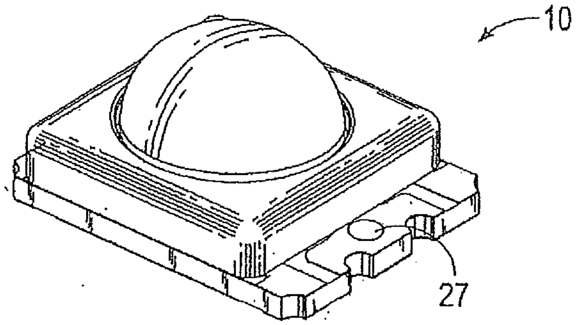


FIG. 1A

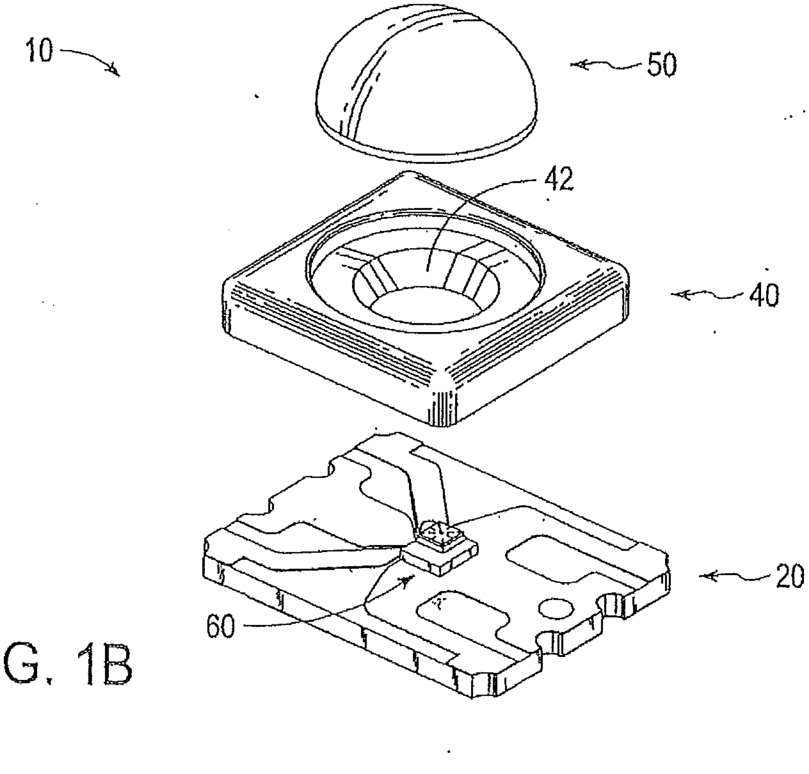


FIG. 1B

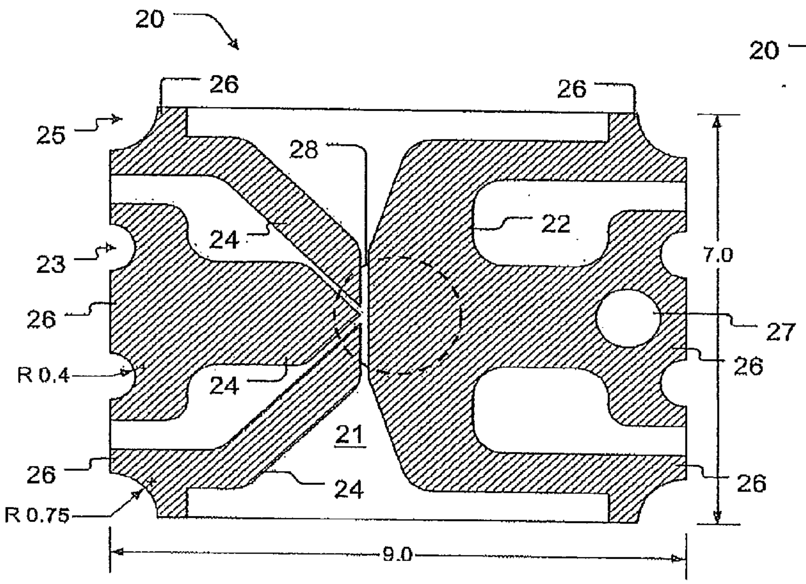


FIG. 2A

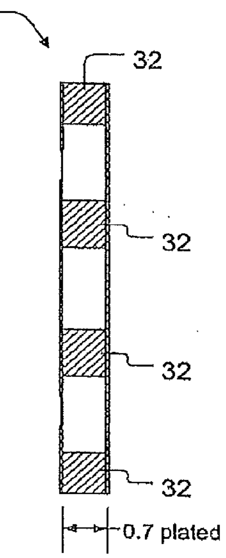


FIG. 2B

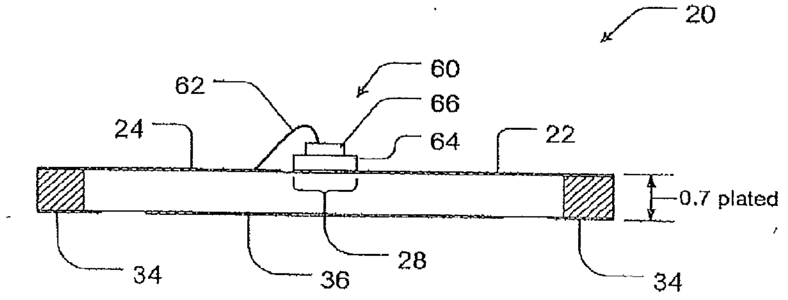


FIG. 2C

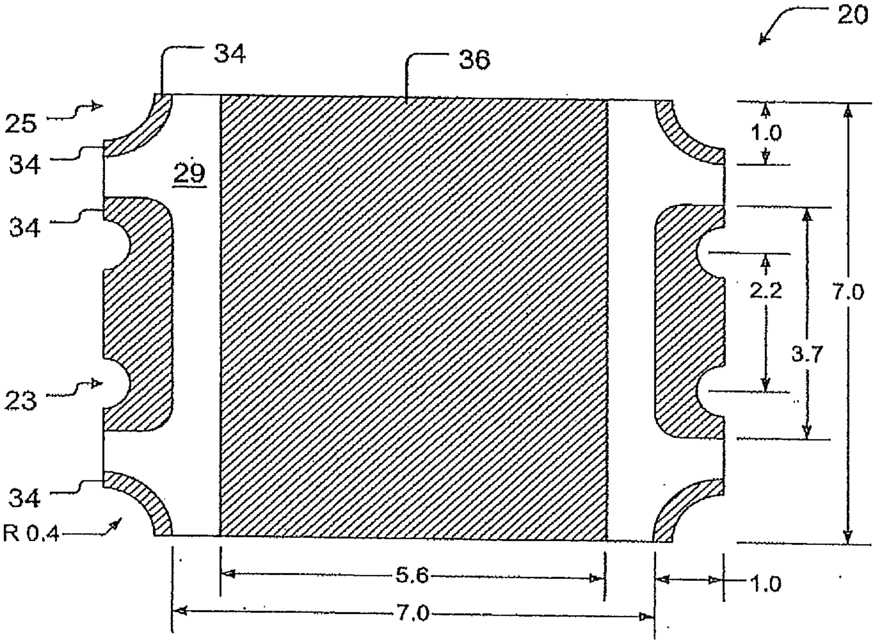

20
34
36
25
34
29
34
23
34
R 0.4
1.0
2.2
3.7
7.0
5.6
7.0
1.0

FIG. 2D

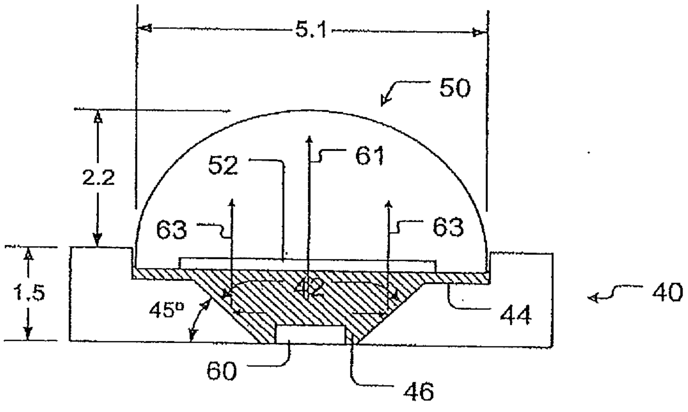

5.1
50
2.2
52
61
63
63
1.5
42
44
40
45°
60
46

FIG. 3

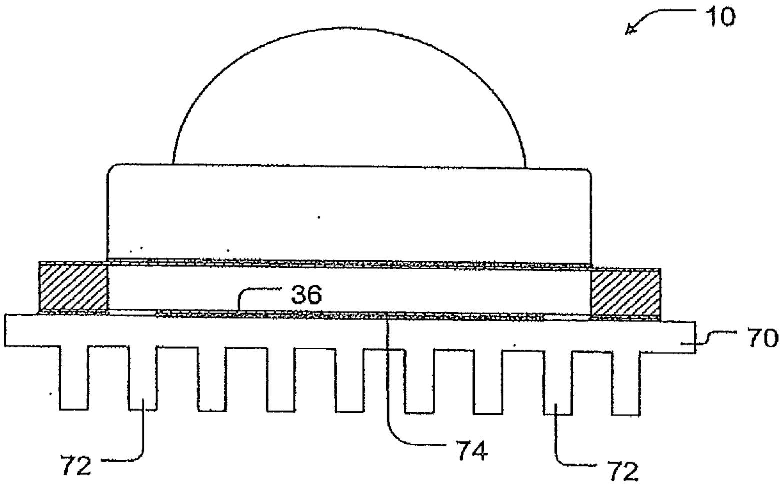


FIG. 4

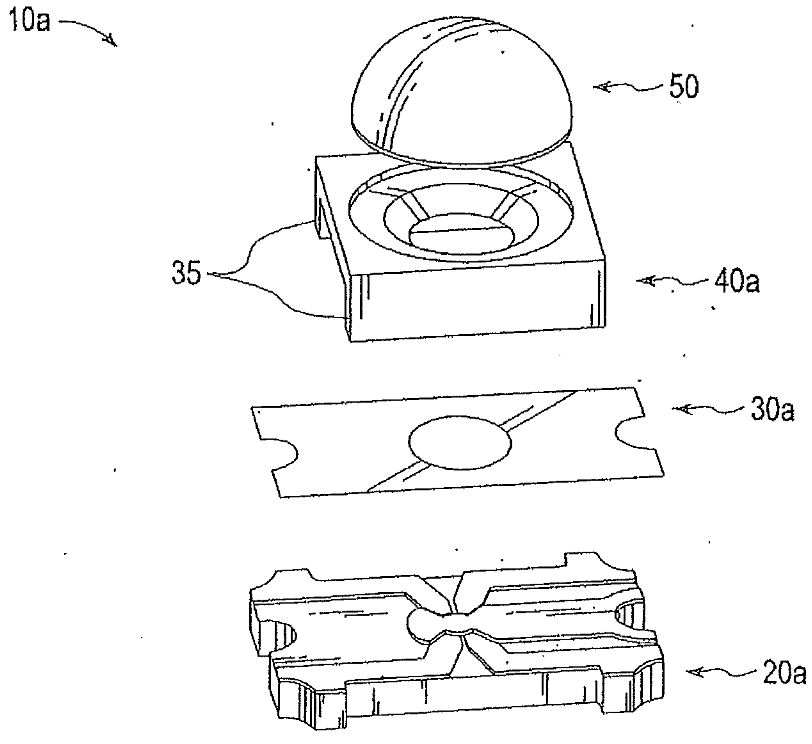


FIG. 5

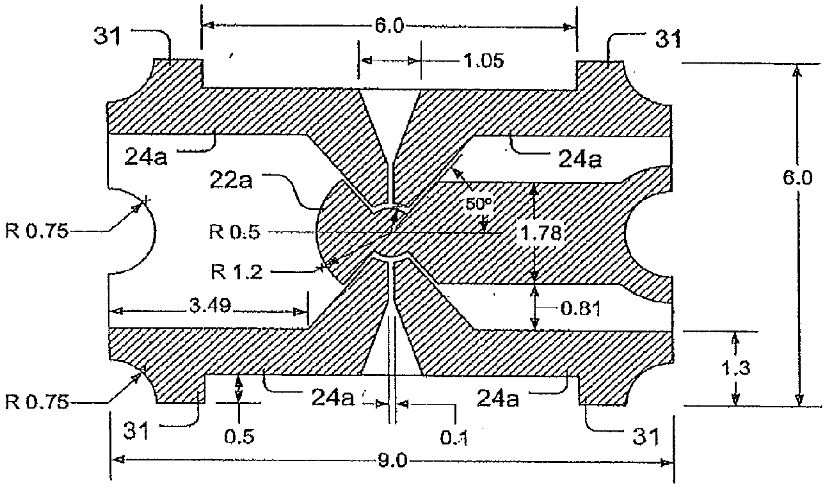


FIG. 6A

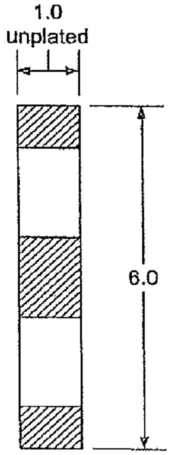


FIG. 6B

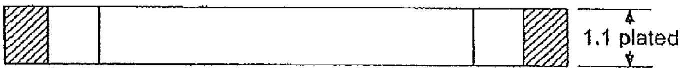


FIG. 6C

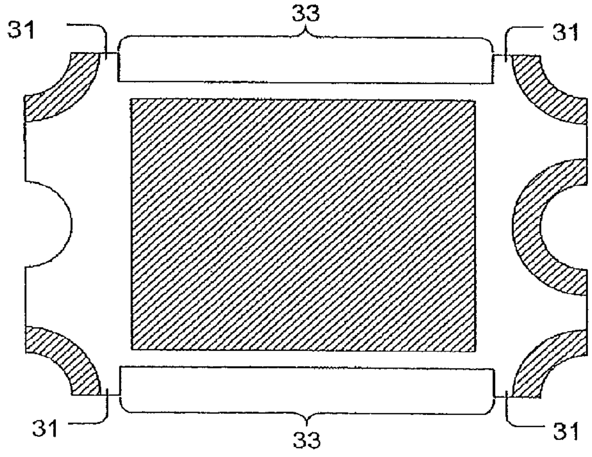


FIG. 6D

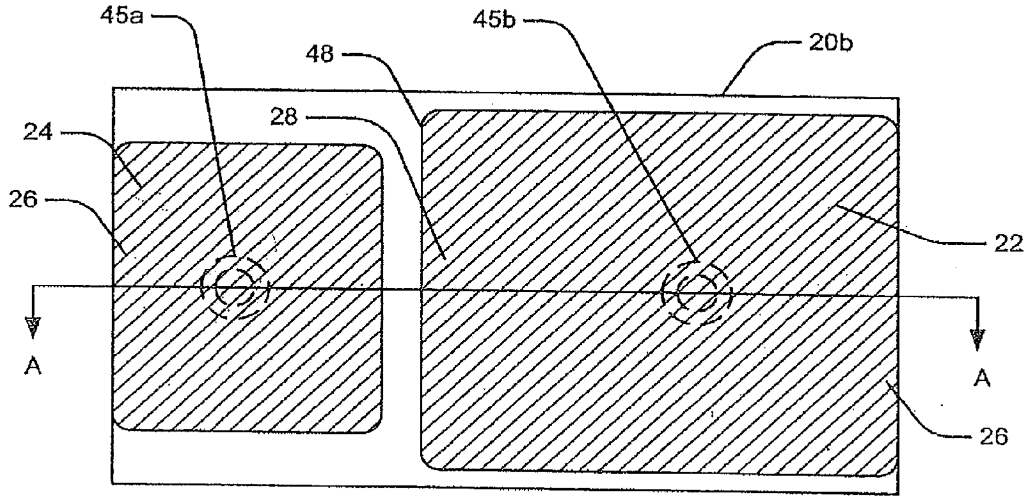


FIG. 7A

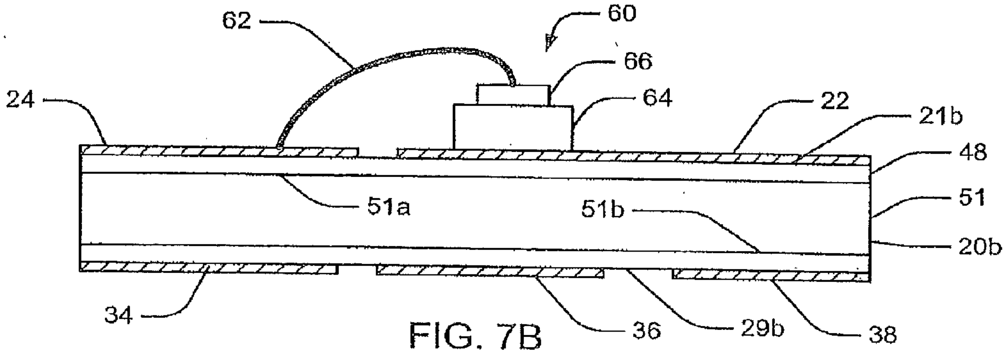


FIG. 7B

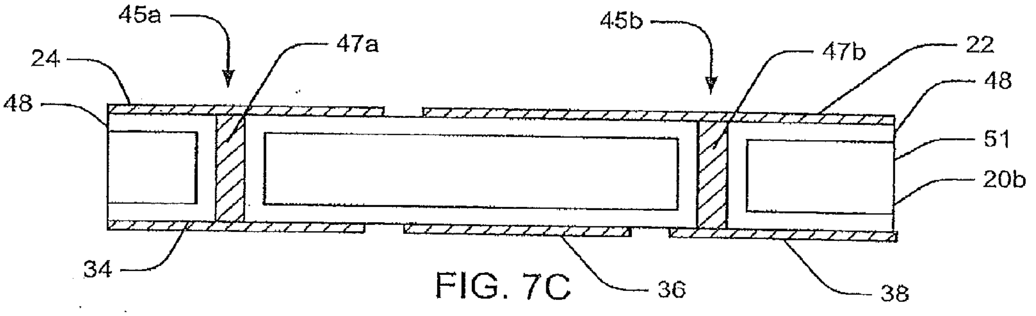


FIG. 7C

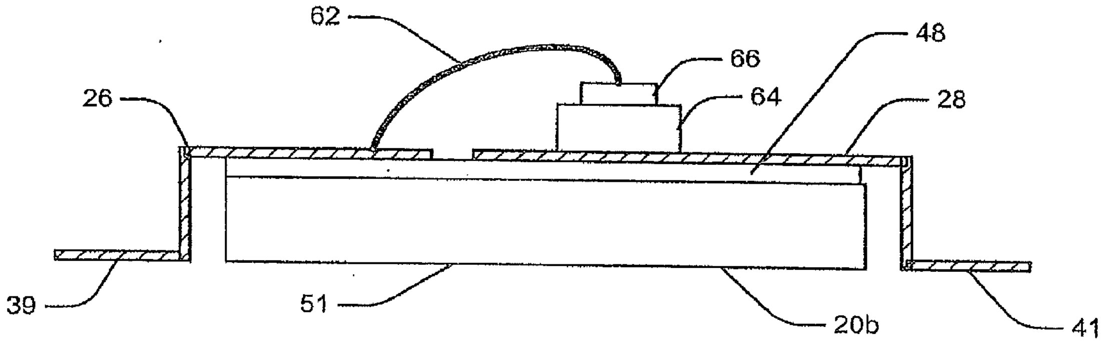


FIG. 8

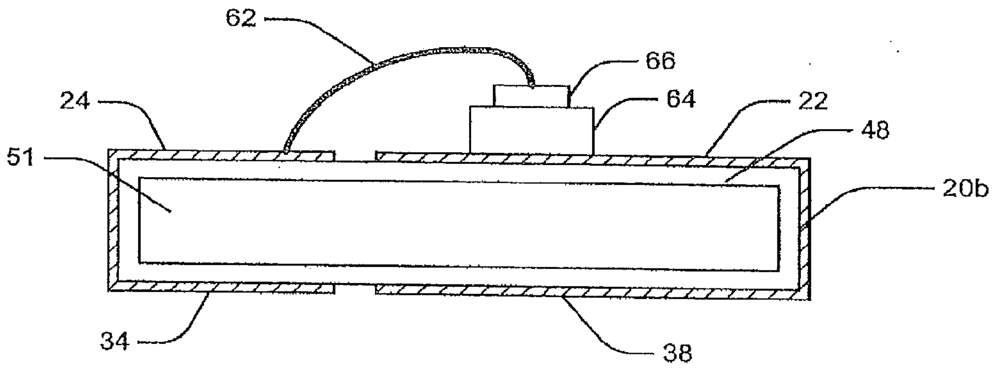


FIG. 9

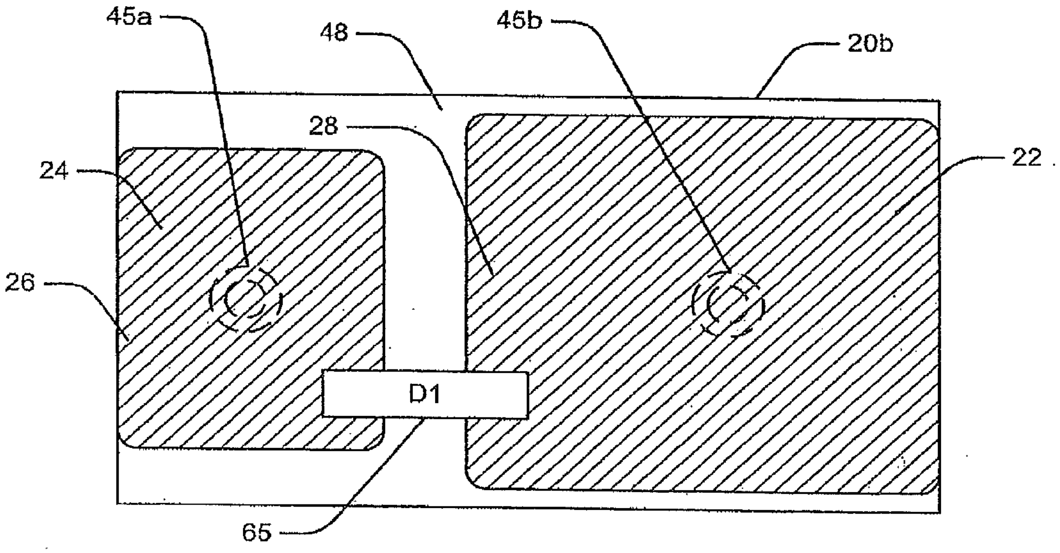


FIG. 10A

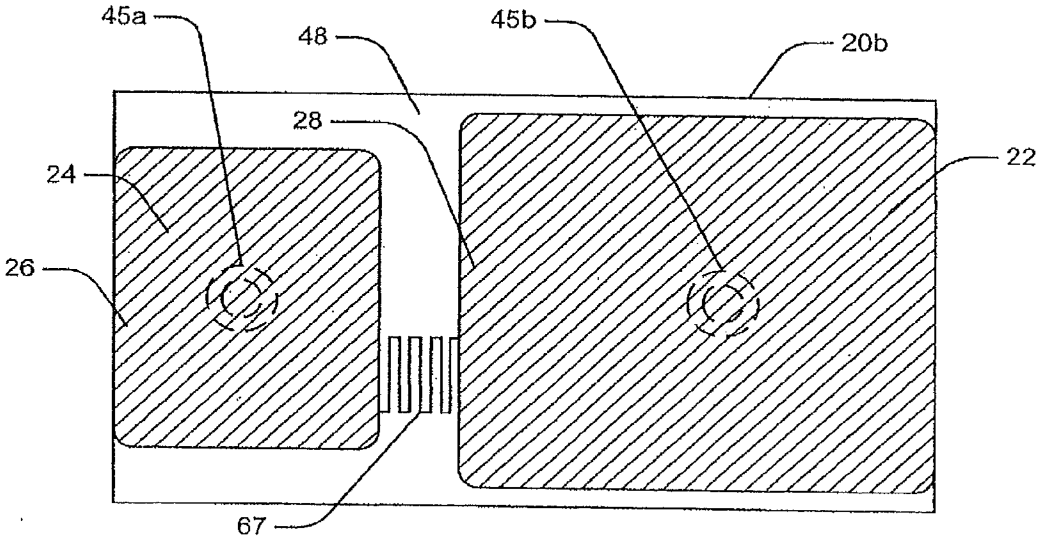


FIG. 10B

POWER SURFACE MOUNT LIGHT EMITTING DIE PACKAGE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of and claims priority to U.S. patent application Ser. No. 13/481,334, filed May 25, 2012, which is a continuation of and claims priority to U.S. patent application Ser. No. 11/689,868 entitled "Power Surface Mount Light Emitting Die Package" filed Mar. 22, 2007, now U.S. Pat. No. 8,188,488, which is a continuation of U.S. patent application Ser. No. 10/692,351 entitled "Power Surface Mount Light Emitting Die Package" filed Oct. 22, 2003, now U.S. Pat. No. 7,244,965, which is a continuation-in-part of U.S. patent application Ser. No. 10/446,532 entitled "Power Surface Mount Light Emitting Die Package" filed May 27, 2003, now U.S. Pat. No. 7,264,378, which claims the benefit of U.S. Provisional Application Ser. No. 60/408,254 filed Sep. 4, 2002. The entire contents of the above Applications and Patents are incorporated by reference herein.

BACKGROUND

[0002] Example embodiments in general relate to packaging semiconductor devices which include light emitting diodes.

[0003] Light emitting diodes (LEDs) are often packaged within leadframe packages. A leadframe package typically includes a molded or cast plastic body that encapsulates an LED, a lens portion, and thin metal leads connected to the LED and extending outside the body. The metal leads of the leadframe package serve as the conduit to supply the LED with electrical power and, at the same time, may act to draw heat away from the LED. Heat is generated by the LED when power is applied to the LED to produce light. A portion of the leads extends out from the package body for connection to circuits external to the leadframe package.

[0004] Some of the heat generated by the LED is dissipated by the plastic package body; however, most of the heat is drawn away from the LED via the metal components of the package. The metal leads are typically very thin and has a small cross section. For this reason, capacity of the metal leads to remove heat from the LED is limited. This limits the amount of power that can be sent to the LED thereby limiting the amount of light that can be generated by the LED.

[0005] To increase the capacity of an LED package to dissipate heat, in one LED package design, a heat sink slug is introduced into the package. The heat sink slug draws heat from the LED chip. Hence, it increases the capacity of the LED package to dissipate heat. However, this design introduces empty spaces within the package that is be filled with an encapsulant to protect the LED chip. Furthermore, due to significant differences in CTE (coefficient of thermal expansion) between various components inside the LED package, bubbles tend to form inside the encapsulant or the encapsulant tends to delaminate from various portions within the package. This adversely affects the light output and reliability of the product. In addition, this design includes a pair of flimsy leads which are typically soldered by a hot-iron. This manufacturing process is incompatible with convenient surface mounting technology (SMT) that is popular in the art of electronic board assembly.

[0006] In another LED package design, the leads of the leadframe package have differing thicknesses extended (in various shapes and configurations) beyond the immediate edge of the LED package body. A thicker lead is utilized as a heat-spreader and the LED chip is mounted on it. This arrangement allows heat generated by the LED chip to dissipate through the thicker lead which is often connected to an external heat sink. This design is inherently unreliable due to significant difference in coefficient of thermal expansion (CTE) between the plastic body and the leadframe material. When subjected to temperature cycles, its rigid plastic body that adheres to the metal leads experiences high degree of thermal stresses in many directions. This potentially leads to various undesirable results such as cracking of the plastic body, separation of the plastic body from the LED chip, breaking of the bond wires, delaminating of the plastic body at the interfaces where it bonds to various parts, or resulting in a combination of these outcomes. In addition, the extended leads increase the package size and its footprint. For this reason, it is difficult to populate these LED packages in a dense cluster on a printed circuit board (PCB) to generate brighter light.

[0007] Another disadvantage of conventional leadframe design is that the thick lead cannot be made or stamped into a fine circuit for flip-chip mounting of a LED—which is commonly used by some manufacturers for cost-effective manufacturing and device performance.

SUMMARY

[0008] An example embodiment of the present invention is directed to a light emitting die package. The package includes a substrate having a first surface and a first conductive lead on the first surface that is insulated from the substrate by an insulating film. The first conductive lead forms a mounting pad for mounting a light emitting device. The package includes a lead electrically connected to the first conductive lead and extending away from the first surface.

[0009] Another example embodiment is directed to a light emitting die package. The package includes a substrate having a first surface and a second surface opposite the first surface, a via hole through the substrate, and a conductive lead extending from the first surface to the second surface. The conductive lead is insulated from the substrate by an insulating film. The package includes a metal contact pad on one of the first and second surfaces electrically connected to the conductive lead. The metal contact pad has a light emitting diode (LED) mounted thereon.

[0010] Another example embodiment is directed to a LED package including a substrate having a first surface, a second surface opposite the first surface, and a first conductive lead on the first surface that is insulated from the substrate by a first insulating film. The first conductive lead forms a mounting pad for mounting a light emitting device. The package includes at least one via hold formed through the substrate. A surface of the via hole is coated with a second insulating film.

[0011] Another example embodiment is directed to a LED package including a substrate having a top surface, a bottom surface, at least one conductive element on the top surface connected to a LED and at least one conductive element attached to the bottom surface. The package includes at least two via holes formed through the substrate. Each via hole includes an electrical conductor therein which electrically connects the at least one conductive elements on the top and bottom surfaces of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Example embodiments will become more fully understood from the detailed description given herein below and the accompanying drawings, wherein like elements are represented by like reference numerals, which are given by way of illustration only and thus are not limitative of the example embodiments.

[0013] FIG. **1**A is a perspective view of a semiconductor die package according to one embodiment of the present invention.

[0014] FIG. **1**B is an exploded perspective view of the semiconductor package of FIG. **1**A.

[0015] FIG. **2**A is a top view of a portion of the semiconductor package of FIG. **1**A.

[0016] FIG. **2**B is a side view of a portion of the semiconductor package of FIG. **1**A.

[0017] FIG. **2**C is a front view of a portion of the semiconductor package of FIG. **1**A.

[0018] FIG. **2**D is a bottom view of a portion of the semiconductor package of FIG. **1**A.

[0019] FIG. **3** is a cut-away side view of portions of the semiconductor package of FIG. **1**A.

[0020] FIG. **4** is a side view of the semiconductor package of FIG. **1**A with additional elements.

[0021] FIG. **5** an exploded perspective view of a semiconductor die package according to another embodiment of the present invention.

[0022] FIG. **6**A is a top view of a portion of the semiconductor package of FIG. **5**.

[0023] FIG. **6**B is a side view of a portion of the semiconductor package of FIG. **5**.

[0024] FIG. **6**C is a front view of a portion of the semiconductor package of FIG. **5**.

[0025] FIG. **6**D is a bottom view of a portion of the semiconductor package of FIG. **5**.

[0026] FIG. **7**A is a top view of a portion of a semiconductor package according to another example embodiment.

[0027] FIG. **7**B is a front view of the portion of a semiconductor package of FIG. **7**A.

[0028] FIG. **7**C is a cut-away front view of the portion of a semiconductor package of FIG. **7**A taken along line A-A.

[0029] FIG. **8** is a side view of a portion of a semiconductor package according to another example embodiment.

[0030] FIG. **9** is a side view of a portion of a semiconductor package according to another example embodiment.

[0031] FIG. **10**A is a top view of a portion of a semiconductor package according to another example embodiment.

[0032] FIG. **10**B is a top view of a portion of a semiconductor package according to another example embodiment.

DETAILED DESCRIPTION

[0033] Example embodiments will now be described with reference to FIGS. **1** through **10**B. As illustrated in the Figures, the sizes of layers or regions are exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of the present invention. Furthermore, various aspects in the example embodiments are described with reference to a layer or structure being formed on a substrate or other layer or structure. As will be appreciated by those of skill in the art, references to a layer being formed "on" another layer or substrate contemplates that additional layers may intervene. References to a layer being formed on another layer or substrate without an intervening layer are described herein as being formed "directly on" the layer or substrate.

[0034] Furthermore, relative terms such as beneath may be used herein to describe one layer or regions relationship to another layer or region as illustrated in the Figures. It will be understood that these terms 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, layers or regions described as "beneath" other layers or regions would now be oriented "above" these other layers or regions. The term "beneath" is intended to encompass both above and beneath in this situation. Like numbers refer to like elements throughout.

[0035] As shown in the figures for the purposes of illustration, example embodiments of the present invention are exemplified by a light emitting die package including a bottom heat sink (substrate) having traces for connecting to a light emitting diode at a mounting pad and a top heat sink (reflector plate) substantially surrounding the mounting pad. A lens covers the mounting pad. In effect, an example die package comprises a two part heat sink with the bottom heat sink utilized (in addition to its utility for drawing and dissipating heat) as the substrate on which the LED is mounted and connected, and with the top heat sink utilized (in addition to its utility for drawing and dissipating heat) as a reflector plate to direct light produced by the LED. Because both the bottom and the top heat sinks draw heat away from the LED, more power can be delivered to the LED, and the LED can thereby produce more light.

[0036] Further, the body of the die package itself may act as the heat sink removing heat from the LED and dissipating it. For this reason, the example LED die package may not require separate heat sink slugs or leads that extend away from the package. Accordingly, the LED die package may be more compact, more reliable, and less costly to manufacture than die packages of the prior art.

[0037] FIG. **1**A is a perspective view of a semiconductor die package **10** according to one embodiment of the present invention and FIG. **1**B is an exploded perspective view of the semiconductor package of FIG. **1**A. Referring to FIGS. **1**A and **1**B, the light emitting die package **10** of the present invention includes a bottom heat sink **20**, a top heat sink **40**, and a lens **50**.

[0038] The bottom heat sink **20** is illustrated in more detail in FIGS. **2**A through **2**D. FIGS. **2**A, **2**B, **2**C, and **2**D provide, respectively, a top view, a side view, a front view, and a bottom view of the bottom heat sink **20** of FIG. **1**A. Further, FIG. **2**C also shows an LED assembly **60** in addition to the front view of the bottom heat sink **20**. The LED assembly **60** is also illustrated in FIG. **1**B. Referring to FIGS. **1**A through **2**D, the bottom heat sink **20** provides support for electrical traces **22** and **24**; for solder pads **26**, **32**, and **34**; and for the LED assembly **60**. For this reason, the bottom heat sink **20** is also referred to as a substrate **20**. In the Figures, to avoid clutter, only representative solder pads **26**, **32**, and **34** are indicated with reference numbers. The traces **22** and **24** and the solder pads **32**, **34**, and **36** can be fabricated using conductive material. Further, additional traces and connections can be fabricated on the top, side, or bottom of the substrate **20**, or layered within the substrate **20**. The traces **22** and **24**, the solder pads **32**, **34**, and **36**, and any other connections can be interconnected to each other in any combination using known methods, for example via holes.

[0039] The substrate **20** is made of material having high thermal conductivity but is electrically insulating, for example, aluminum nitride (AlN) or alumina (Al.sub.2O.sub.3). Dimensions of the substrate **20** can vary widely depending on application and processes used to manufacture the die package **10**. For example, in the illustrated embodiment, the substrate **20** may have dimensions ranging from fractions of millimeters (mm) to tens of millimeters. Although the present invention is not limited to particular dimensions, one specific embodiment of the die package **10** of the present invention is illustrated in Figures with the dimensions denoted therein. All dimensions shown in the Figures are in millimeters (for lengths, widths, heights, and radii) and degrees (for angles) except as otherwise designated in the Figures, in the Specification herein, or both.

[0040] The substrate **20** has a top surface **21**, the top surface **21** including the electrical traces **22** and **24**. The traces **22** and **24** provide electrical connections from the solder pads (for example top solder pads **26**) to a mounting pad **28**. The top solder pads **26** are portions of the traces **22** and **24** generally proximal to sides of the substrate **20**. The top solder pads **26** are electrically connected to side solder pads **32**. The mounting pad **28** is a portion of the top surface (including portions of the trace **22**, the trace **24**, or both) where the LED assembly **60** is mounted. Typically the mounting pad **28** is generally located proximal to center of the top surface **21**. In alternative embodiments of the present invention, the LED assembly **60** can be replaced by other semiconductor circuits or chips.

[0041] The traces **22** and **24** provide electrical routes to allow the LED assembly **60** to electrically connect to the solder pads **26**, **32**, or **34**. Accordingly, some of the traces are referred to as first traces **22**, while other traces are referred to as second traces **24**. In the illustrated embodiment, the mounting pad **28** includes portions of both the first traces **22** and the second traces **24**. In the illustrated example, the LED assembly **60** is placed on the first trace **22** portion of the mounting pad **28** thereby making contact with the first trace **22**. In the illustrated embodiment, a top of the LED assembly **60** and the second traces **24** are connected to each other via a bond wire **62**. Depending on the construction and orientation of LED assembly **60**, first traces **22** may provide anode (positive) connections and second traces **24** may comprise cathode (negative) connections for the LED assembly **60** (or vice versa).

[0042] The LED assembly **60** can include additional elements. For example, in FIGS. **1**B and **2**C, the LED assembly **60** is illustrated including an LED bond wire **62**, an LED subassembly **64**, and a light emitting diode (LED) **66**. Such an LED subassembly **64** is known in the art and is illustrated for the purposes of discussing the invention and is not meant to be a limitation of the present invention. In the Figures, the LED assembly **60** is shown die-attached to the substrate **20**. In alternative embodiments, the mounting pad **28** can be configured to allow flip-chip attachment of the LED assembly **60**. Additionally, multiple LED assemblies can be mounted on the mounting pad **28**. In alternative embodiments, the LED assembly **60** can be mounted over multiple traces. This is especially true if flip-chip technology is used.

[0043] The topology of the traces **22** and **24** can vary widely from the topology illustrated in the Figures while still remaining within the scope of the example embodiments of the present invention. In the Figures, three separate cathode (negative) traces **24** are shown to illustrate that three LED assemblies can be placed on the mounting pad **28**, each connected to a different cathode (negative) trace; thus, the three LED assemblies may be separately electrically controllable. The traces **22** and **24** are made of conductive material such as gold, silver, tin, or other metals. The traces **22** and **24** can have dimensions as illustrated in the Figures and are of a thickness on the order of microns or tens of microns, depending on application. In an example, the traces **22** and **24** can be 15 microns thick. FIGS. **1**A and **2**A illustrate an orientation marking **27**. Such markings can be used to identify the proper orientation of the die package **10** even after assembling the die package **10**. The traces **22** and **24**, as illustrated, can extend from the mounting pad **28** to sides of the substrate **20**.

[0044] Continuing to refer to FIGS. **1**A through **2**D, the substrate **20** defines semi-cylindrical spaces **23** and quarter-cylindrical spaces **25** proximal to its sides. In the Figures, to avoid clutter, only representative spaces **23** and **25** are indicated with reference numbers. The semi-cylindrical spaces **23** and the quarter-cylindrical spaces **25** provide spaces for solder to flow-through and solidify-in when the die package **10** is attached to a printed circuit board (PCB) or another apparatus (not shown) to which the die package **10** is a component thereof. Moreover, the semi-cylindrical spaces **23** and the quarter-cylindrical spaces **25** provide convenient delineation and break points during the manufacturing process.

[0045] The substrate **20** can be manufactured as one individual section of a strip or a plate having a plurality of adjacent sections, each section being a substrate **20**. Alternatively, the substrate **20** can be manufactured as one individual section of an array of sections, the array having multiple rows and columns of adjacent sections. In this configuration, the semi-cylindrical spaces **23** and quarter-cylindrical spaces **25** can be utilized as tooling holes for the strip, the plate, or the array during the manufacturing process.

[0046] Furthermore, the semi-cylindrical spaces **23** and the quarter-cylindrical spaces **25**, combined with scribed grooves or other etchings between the sections, assist in separating each individual substrate from the strip, the plate, or the wafer. The separation can be accomplished by introducing physical stress to the perforation (semi through holes at a close pitch) or scribe lines made by laser, or premolded, or etched lines (crossing the semi-cylindrical spaces **23** and the quarter-cylindrical spaces **25**) by bending the strip, the plate, or the wafer. These features simplify the manufacturing process and thus reduce costs by eliminating the need for special carrier fixtures to handle individual unit of the substrate **20** during the manufacturing process. Furthermore, the semi-cylindrical spaces **23** and the quarter-cylindrical spaces **25** serve as via holes connecting the top solder pads **26**, the side solder pads **32**, and the bottom solder pads **34**.

[0047] The substrate **20** has a bottom surface **29** including a thermal contact pad **36**. The thermal contact pad **36** can be fabricated using a material having a high thermally and electrically conductive properties such as gold, silver, tin, or another material including but not limited to precious metals.

[0048] FIG. **3** illustrates a cut-away side view of portions of the semiconductor package of FIGS. **1**A and **1**B. In particular, the FIG. **3** illustrates a cut-away side view of the top heat sink **40** and the lens **50**. Referring to FIGS. **1**A, **1**B, and **3**, the top heat sink **40** is made from a material having high thermal conductivity such as aluminum, copper, ceramics, plastics, composites, or a combination of these materials. A high temperature, mechanically tough, dielectric material can be used to overcoat the traces **22** and **24** (with the exception of the central die-attach area) to seal the traces **22** and **24** and provide protection from physical and environmental harm such as scratches and oxidation. The overcoating process can be a part of the substrate manufacturing process. The overcoat, when used, may insulate the substrate **20** from the top heat sink **40**. The overcoat may then be covered with a high temperature adhesive such as thermal interface material manufactured by THERMOSET that bonds the substrate **20** to the top heat sink **40**.

[0049] The top heat sink **40** may include a reflective surface **42** substantially surrounding the LED assembly **60** mounted on the mounting pad **28** (of FIGS. **2**A and **2**C). When the top heat sink **40** is used to dissipate heat generated by the LED in the die package **10**, it can be "top-mounted" directly onto an external heat sink by an adhesive or solder joint to dissipate heat efficiently. In another embodiment, if heat has to be dissipated by either a compressible or non-compressible medium such as air or cooling fluid, the top heat sink **40** may be equipped with cooling fins or any feature that will enhance heat transfer between the top heat sink **40** and the cooling medium. In both of these embodiments, the electrical terminals and the bottom heat sink **20** of the die package **10** can still be connected to its application printed circuit board (PCB) using, for example, the normal surface-mount-technology (SMT) method.

[0050] The reflective surface **42** reflects portions of light from the LED assembly **60** as illustrated by sample light rays **63**. Other portions of the light are not reflected by the reflective surface **42** as illustrated by sample light ray **61**. Illustrative light rays **61** and **63** are not meant to represent light traces often use in the optical arts. For efficient reflection of the light, the top heat sink **40** is preferably made from material that can be polished, coined, molded, or any combination of these. Alternatively, to achieve high reflectivity, the optical reflective surface **42** or the entire heat sink **40** can be plated or deposited with high reflective material such as silver, aluminum, or any substance that serves the purpose. For this reason, the top heat sink **40** is also referred to as a reflector plate **40**. The reflector plate **40** is made of material having high thermal conductivity if and when required by the thermal performance of the package **10**.

[0051] In the illustrated embodiment, the reflective surface **42** is illustrated as a flat surface at an angle, for example 45 degrees, relative to the reflective plate's horizontal plane. The example embodiments are not limited to the illustrated embodiment. For example, the reflective surface **42** can be at a different angle relative to the reflective plate's horizontal plane. Alternatively, the reflective plate can have a parabolic, toroid or any other shape that helps to meet the desired spectral luminous performance of the package.

[0052] The reflective plate **40** includes a ledge **44** for supporting and coupling with the lens **50**. The LED assembly **60** is encapsulated within the die package **10** (of FIGS. **1**A and **1**B) using encapsulation material **46** such as, for example only, soft and elastic silicones or polymers. The encapsulation material **46** can be a high temperature polymer with high light transmissivity and refractive index that matches or closely matches refractive index of the lens **50**, for example. The encapsulant **46** is not affected by most wavelengths that alter its light transmissivity or clarity.

[0053] The lens **50** is made from material having high light transmissivity such as, for example only, glass, quartz, high temperature and transparent plastic, or a combination of these materials. The lens **50** is placed on top of and adheres to the encapsulation material **46**. The lens **50** is not rigidly bonded to the reflector **40**. This "floating lens" design enables the encapsulant **46** to expand and contract under high and low temperature conditions without difficulty.

[0054] For instance, when the die package **10** is operating or being subjected to a high temperature environment, the encapsulant **46** experiences greater volumetric expansion than the cavity space that contains it. By allowing the lens **50** to float up somewhat freely on top of the encapsulant **46**, no encapsulant will be squeezed out of its cavity space. Likewise, when the die package **10** is subjected to a cold temperature, the encapsulant **46** will contract more than the other components that make up the cavity space for the encapsulant **46**; the lens will float freely on top of the encapsulant **46** as the latter shrinks and its level drops. Hence, the reliability of the die package **10** is maintained over relatively large temperature ranges as the thermal stresses induced on the encapsulant **46** is reduced by the floating lens design.

[0055] In some embodiments, the lens **50** defines a recess **52** (See FIG. **3**) having a curved, hemispherical, or other geometry, which can be filled with optical materials intended to influence or change the nature of the light emitted by the LED chip(s) before it leaves the die package **10**. Examples of one type of optical materials include luminescence converting phosphors, dyes, fluorescent polymers or other materials which absorb some of the light emitted by the chip(s) and re-emit light of different wavelengths. Examples of another type of optical materials include light diffusants such as calcium carbonate, scattering particles (such as Titanium oxides) or voids which disperse or scatter light. Any one or a combination of the above materials can be applied on the lens **50** to obtain certain spectral luminous performance.

[0056] FIG. **4** illustrates the die package **10** coupled to an external heat sink **70**. Referring to FIG. **4**, the thermal contact pad **36** can be attached to the external heat sink **70** using epoxy, solder, or any other thermally conductive adhesive, electrically conductive adhesive, or thermally and electrically conductive adhesive **74**. The external heat sink **70** can be a printed circuit board (PCB) or other structure that draws heat from the die package **10**. The external heat sink can include circuit elements (not shown) or heat dissipation fins **72** in various configurations.

[0057] An example embodiment having an alternate configuration is shown in FIGS. **5** through **6**D. Portions of this second embodiment are similar to corresponding portions of the first embodiment illustrated in FIGS. **1**A through **4**. For convenience, portions of the second embodiment as illustrated in FIGS. **5** through **6**D that are similar to portions of the first embodiment are assigned the same reference numerals, analogous but changed portions are assigned the same reference numerals accompanied by letter "a," and different portions are assigned different reference numerals.

[0058] FIG. **5** is an exploded perspective view of an LED die package **10***a* in accordance with other embodiments of the present invention. Referring to FIG. **5**, the light emitting die package **10***a* of the present invention includes a bottom heat sink (substrate) **20***a*, a top heat sink (reflector plate) **40***a*, and a lens **50**.

[0059] FIGS. **6**A, **6**B, **6**C, and **6**D, provide, respectively, a top view, a side view, a front view, and a bottom view of the substrate **20***a* of FIG. **5**. Referring to FIGS. **5** through **6**D, the substrate **20***a* includes one first trace **22***a* and four second traces **24***a*. Traces **22***a* and **24***a* are configured differently than traces **22** and **24** of FIG. **2**A. The substrate **20***a* includes flanges **31** that define latch spaces **33** for reception of legs **35**

of the reflector plate **40***a*, thereby mechanically engaging the reflector plate **40***a* with the substrate **20***a*.

[0060] Additional example embodiments are illustrated in FIGS. **7**A through **10**B. According to these embodiments, a substrate for a high power light emitting device includes a thermally and electrically conductive plate having first and second surfaces. The plate may comprise a metal such as copper, aluminum or alloys of either. A thin, thermally conductive insulating film is formed on the first surface of the metal plate. In some embodiments, the thermally conductive insulating film comprises a ceramic/polymer film such as the Thermal Clad film available from by The Bergquist Company of Chanhassen, Minn., USA.

[0061] Conductive elements such as metal traces and/or metal leads may be formed on the ceramic/polymer film. Since the ceramic/polymer film is insulating, the conductive traces are not in electrical contact with the metal plate. A conductive element may form or be electrically connected to a mounting pad adapted to receive an electronic device. As discussed above in connection with the embodiments illustrated in FIGS. **1**-**6**, the topology of the metal traces may vary widely while still remaining within the scope of the example embodiments.

[0062] An LED assembly may be bonded to the mounting pad for example by means of soldering, thermo-sonic bonding or thermo-compression bonding. Heat generated by the LED may be dissipated at least in part through the metal plate. Since the substrate itself may act as a heat sink, the need for bonding an additional heat sink to the structure may be reduced or eliminated. However, an additional heat sink may be placed in thermal communication with the metal plate so that heat may be drawn away from the operating device more efficiently.

[0063] In one embodiment, one or more via holes may be formed through the insulating film and the metal plate. The via holes may be internally coated with an insulating material such as the ceramic/polymer film. Electrical conductors such as electrically conductive traces may be formed in the via hole to electrically connect conductive elements on the first surface of the substrate to conductive elements on the second surface of the substrate. A substrate according to such an embodiment may be mounted on a surface such as a printed circuit board without the use of metal leads, which may result in a more mechanically robust package.

[0064] A substrate according to example embodiments may also include electronic circuitry such as a discrete zener diode and/or a resistor network for electrostatic discharge (ESD) and/or over-voltage protection.

[0065] Although not illustrated in FIGS. **7**-**10**, the substrate may further include features such as the semi-cylindrical and quarter-cylindrical spaces, orientation markings, side bond pads, flanges and other features illustrated in FIGS. **1**-**6**.

[0066] Portions of the embodiments illustrated in FIGS. **7**A through **10**B are similar to corresponding portions of the embodiments illustrated in FIGS. **1** through **6**D. For convenience, portions of the embodiment as illustrated in FIGS. **7**A through **10**B that are similar to portions of the first embodiment are assigned the same reference numerals, analogous but changed portions are assigned the same reference numerals accompanied by letter "b," and different portions are assigned different reference numerals.

[0067] Referring now to FIG. **7**A, a substrate **20***b* according to another embodiments of the present invention is illustrated. FIGS. **7**A and **7**B provide, respectively, a top view and a front view of the substrate **20***b*. Further, FIG. **7**B also shows an LED assembly **60** in addition to the front view of the substrate **20***b*. The substrate **20***b* includes a thermally and electrically conductive plate **51** having first and second surfaces **51***a* and **51***b*. The plate **51** may comprise a metal such as copper, aluminum or alloys of either. A thin, thermally conductive insulating film **48** is formed on at least portions of the first surface **51***a* of the metal plate **51**. In some embodiments, the thermally conductive insulating film **48** comprises a ceramic/polymer film such as the Thermal Clad film available from by The Bergquist Company of Chanhassen, Minn., USA. In addition, a thermally conductive insulating film **49** may be formed on the second surface **51***b* of plate **51**, as well as side surfaces.

[0068] The substrate **20***b* provides support for electrically conductive elements such as electrical traces **22** and **24**; for solder pads **26**; and for the LED assembly **60**. Further, additional traces and connections can be fabricated on the top, side, or bottom of the substrate **20***b*, or layered within the substrate **20***b*. The traces **22** and **24**, the solder pads **26**, and any other connections can be interconnected to each other in any combinations using known methods, for example via holes.

[0069] The substrate **20***b* has a top surface **21***b*, the top surface **21***b* including the electrical traces **22** and **24**. The traces **22** and **24** provide electrical connections from the solder pads (for example top solder pads **26**) to a mounting pad **28**. The top solder pads **26** may comprise portions of the traces **22** and **24** generally proximal to sides of the substrate **20***b*. The mounting pad **28** is a portion of the top surface (including portions of the trace **22**, the trace **24**, or both) where the LED assembly **60** is mounted. Typically the mounting pad **28** is generally located proximal to center of the top surface **21***b*. In alternative embodiments of the present invention, the LED assembly **60** can be replaced by other semiconductor circuits or chips.

[0070] The topology of the traces **22** and **24** can vary widely from the topology illustrated in the Figures while still remaining within the scope of the example embodiments. In the Figures, only one cathode (negative) and one anode (positive) trace is shown. However, multiple cathode or anode traces may be included on the substrate **20***b* to facilitate the mounting of plural LED assemblies on the mounting pad **28**, each connected to a different cathode or anode trace; thus, the three LED assemblies may be separately electrically controllable. The traces **22** and **24** are made of conductive material such as gold, silver, tin, or other metals.

[0071] The substrate **20***b* has a bottom surface **29***b* including a thermal contact pad **36**. The thermal contact pad can be fabricated using material having high heat conductivity such as gold, silver, tin, or other material including but not limited to precious metals.

[0072] FIG. **7**C illustrates a cut-away front view of portions of the substrate **20***b* taken along section line A-A of FIG. **7**A. As shown in FIG. **7**C, one or more via holes **45***a*, **45***b* may be formed through the substrate **20***b*. The via holes **45***a*, **45***b* may be internally coated with an insulating material such as the ceramic/polymer film. Electrical conductors such as electrically conductive traces **47***a*, **47***b* may be formed in the via holes and may electrically connect conductive elements on the first surface of the substrate to conductive elements on the second surface of the substrate. As illustrated in FIG. **7**C, a conductive trace **47***a* in via hole **45***a* connects trace **24** on the first side **21***b*, or the top surface **21***b*, of the substrate **20***b* to solder pad **34** on the second side **29***b*, or the bottom surface **29***b*, of the substrate **20***b*. Likewise, a conductive trace **47***b* extending through via hole **45***b* connects conductive trace **22** to a bond pad **38**.

[0073] A substrate according to such an embodiment may be mounted on a surface such as a printed circuit board without the use of metal leads, which may result in a more mechanically robust package.

[0074] As discussed above, a high temperature, mechanically tough, dielectric material can be used to overcoat the traces **22** and **24** (with the exception of the central die-attach area **28**) to seal the traces **22** and **24** and provide protection from physical and environmental harm such as scratches and oxidation. The overcoating process can be a part of the substrate manufacturing process. The overcoat, when used, also insulates the traces **22** and **24** from the top heat sink **40**. The overcoat may then be covered with a high temperature adhesive such as thermal interface material manufactured by THERMOSET that bonds the substrate **20***b* with the top heat sink **40**.

[0075] Other embodiments that do not utilize via holes are illustrated in FIGS. **8** and **9**. As illustrated in FIG. **8**, the conductive traces **22**, **24** may form or be attached to metal leads **39**, **41** which extend away from the package and which may be mounted directly to a circuit board. In such an embodiment, only the first surface **21***b* of the substrate **20***b* may include an electrically insulating, thermally conductive film **48**.

[0076] FIG. **9** illustrates an embodiment in which conductive traces **22**, **24** extend down the sidewalls of the substrate **20***b* to contact bond pads **34** and **38** on the second surface of the substrate **20***b*. Such a configuration may permit the package to be mounted directly onto a circuit board without the use of metal leads or via holes.

[0077] As illustrated in FIGS. **10**A and **10**B, the substrate **20***b* may be configured to include electronic circuitry such as a discrete zener **65** diode, a resistor network **67**, other electronic elements, or any combination of these. Such electronic circuitry can be connected between the traces **22** and **24** which may operate as anode/or cathode elements. The electronic circuitry can be used for various purposes, for example, to prevent electrostatic discharge (ESD), for over-voltage protection, or both. In the illustrated examples, the zener diode D1 **65** connected between the trace **22** and the trace **24** as illustrated in FIG. **10**B may prevent an excessive reverse voltage from being applied to an optoelectronic device mounted on the substrate **20***b*. Similarly, the resistor network **67** such as printed resistor **67** may provide ESD protection to a device mounted on the substrate **20**.

[0078] The example embodiments of the present invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the exemplary embodiments of the present invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. A light emitting die package, comprising:
a substrate comprising a top surface, a bottom surface and a plurality of sides;
a light emitting diode (LED) mounted on the top surface of the substrate;
a thermal pad on or exposed on the bottom surface of the substrate that opposes the surface upon which the LED is mounted; and
a plurality of solder pads spaced apart from the thermal pad on the bottom surface of the substrate.

2. The package of claim **1**, further comprising a plurality of traces disposed on the top surface of the substrate.

3. The package of claim **2**, wherein the LED is connected to the plurality of traces.

4. The package of claim **1**, wherein at least one of the plurality of solder pads extends along one side of the plurality of sides of the substrate and between the top and bottom surfaces.

5. The package of claim **1**, wherein the thermal pad comprises a metal.

7. The package of claim **1**, further comprising a reflector coupled to the substrate and substantially surrounding the LED, the reflector defining a reflection surface.

8. The package of claim **7**, wherein the reflector is composed of a material having high thermal conductivity.

9. The package of claim **7**, wherein the reflector and substrate serve as heat sinks for dissipating heat generated by the LED.

10. The package of claim **1**, further comprising an encapsulant covering the LED.

11. The package of claim **10**, wherein the encapsulant is disposed within a portion of the reflector.

12. The package of claim **10**, wherein the encapsulant is composed of an optically clear polymer material.

13. The package of claim **1**, further comprising a lens covering the LED.

14. The package of claim **13**, wherein the lens sits on and adheres to a portion of the encapsulant, the lens being movable relative to one or more portions of the package.

15. The package of claim **10**, wherein the encapsulant comprises silicone.

16. The package of claim **1**, wherein the substrate is electrically insulating.

17. The package of claim **16**, wherein the electrically insulating substrate comprises aluminum nitride or alumina.

18. The package of claim **1**, wherein some of the plurality of solder pads are disposed on opposing sides of the bottom surface of the substrate.

19. The package of claim **1**, wherein some of the plurality of solder pads are disposed on opposing sides of the top surface of the substrate.

20. The package of claim **1**, wherein some of the plurality of solder pads are disposed on opposite sides from other of the plurality of solder pads.

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