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(54) **Title:** SOLID STATE LIGHT SOURCE MOUNTED DIRECTLY ON ALUMINUM SUBSTRATE FOR BETTER THERMAL PERFORMANCE AND METHOD OF MANUFACTURING THE SAME

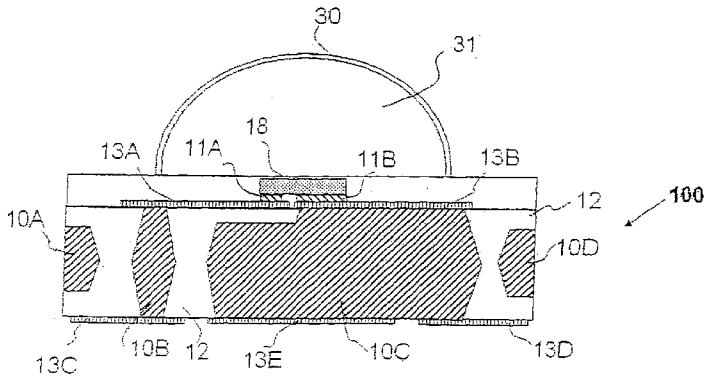

FIGURE 2

(57) **Abstract:** In accordance with the present invention, a solid state light source packaged for high temperature operation comprises an Aluminum Metal substrate (100) including an overlying plurality of electrical circuitries (13 A-E) isolated with dielectric between the circuitry metallization and metal substrate, a light source die (18) direct mounted overlying the metal base (1 OA-D) with no dielectric (12) in between, an underlying electrical connection pads connected to the overlying electrical circuitries using vertically isolated bulk metal without drilling, an underlying electrical circuitries (13A- E) connected directly to the bulk metal (1 OA-D) with no dielectric (12) in between and an over-molded compound (33) for protection and light shaping purposes. The selective electrical isolation and direct mounting of the heat source to the bulk metal (1 OA-D) allow lowest thermal resistances. Similar design with a plurality of the same is applicable for more than one or matrix LED assembly.

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SOLID STATE LIGHT SOURCE MOUNTED DIRECTLY ON ALUMINUM SUBSTRATE FOR BETTER THERMAL PERFORMANCE AND METHOD OF MANUFACTURING THE SAME

FIELD OF THE INVENTION

This invention relates to a thermally efficient solid state light source and in particular, a high-power light emitting diode (hereinafter referred to as "LED") light source packaged in unit or matrix format for high temperature operation.

BACKGROUND ART

Light Emitting Diode (LED) has extended from the low power signaling or lighting indicator applications to higher power, high brightness illumination applications. About 85% of the power is converted to heat. The drive to increase brightness in the tiny light source requires higher power resulting in rapid increase in device junction temperature. The increase in temperature translates to poor light extraction efficiency and high device failure rate. Accordingly, instead of limited by the thermal limits of the packaging, the design challenge is to interface generated heat away from the light source efficiently and cost effectively.

Prior art LED packages comes in many different types and configurations. FIG. 1 shows the various high powered LED packages. Some of the packages have package thermal resistance as high as 25°C/W. The best alternative material is metal; and contradictory, the best thermal material also has the best electrical properties. One commonality of the Prior Art package design is the attempt to work-around these conflicting properties by trying to isolate the electrical connections from the bulk metal base with a very thin layer of thermally conductive dielectric which if too thin will result in lower breakdown voltage.

Surface Mount LED requires underlying electrical pads; thus, requiring connections to the overlying electrical circuitries by plated-through-hole vias or edge connection. The

multi-step integrated package either using the copper lead-frame or FR4 or composite material or ceramic approach are cumbersome to produce. Ceramic substrate is a good alternative but a much costlier solution. Accordingly there is a need for an improved high power light source packaged for high temperature operation.

SUMMARY OF THE INVENTION

In accordance with the present invention, a solid state light source packaged for high temperature operation comprises an Aluminum Metal substrate including an overlying plurality of electrical connections isolated with dielectric between the circuitry metallization and metal substrate, a light source die direct mounted overlying the metal base with no dielectric in between, a underlying electrical connection pads connected to the overlying electrical circuitries using vertically isolated bulk metal without drilling, an underlying thermal pad connected directly to the bulk metal with no dielectric in between and an over-mold compound for protection and light shaping purposes. The selective electrical isolation and direct mounting of the heat source to the bulk metal exhibits lowest thermal resistances.

Similar design with a plurality of the same is applicable for more than one LED or matrix LED assembly. The preferred embodiment for matrix or board level high volume manufacturing consists of a pre-stamped matrix substrate with either stamp-outs or break-off tabs or v-cut using stamping approach around the perimeter of the individual unit single-layer circuitries or multi-layer circuitries on a metal core substrate. The said matrix substrate can be subsequently singulated by hand or by simple automated jigging process.

The same stamping process allows multi-level mould or cavity design to be pressure-stamped or coined onto the same substrates. The newly formed surfaces can be used for better mold compound anchoring. The created cavity can serves as a light shaping reflector.

Another feature of the matrix substrate in the present invention is the matrix Design-for-testability features specifically the designing in of the inter-device common electrical connectivity to facilitate matrix or parallel testing or matrix burn-in of assembled components prior to or after the encapsulation process.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawings the preferred embodiments from an inspection of which when considered in connection with the following description, the invention, its construction and operation and many of its advantages would be readily understood and appreciated.

FIG. 1 shows example of Prior Art High Power Assembly;

FIG. 2 is the schematic cross section of the first embodiment of the present invention;

FIG. 3A, 3B, 3C, 3D, 3E and 3F illustrate alternative embodiments with different configuration of dielectric with and without light source shaping molding;

FIG. 4 shows the various views of matrix pre-stamped substrate according to the present invention.

It is to be understood that these drawings are for illustrating the concepts of the invention and are not to scale.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This description is divided into two parts. Part I describes the structure and features of the light source packaged using aluminum substrate for high power LED in accordance

with the invention and illustrate exemplary embodiments. Part II describes the novel high volume manufacturing approach with Design-For-Testability features in matrix format and a cost effective singulation methodology using pre-stamped substrate as claimed in Part I.

PART I: Light source on Aluminum Substrate package

Referring to the drawings, FIG. 2 is a schematic cross section view of a surface mountable LED package (1) for high temperature operation.

The aluminum metal base has been prefabricated with the required circuitries resulting in electrical circuitries (13A, 13B) on the first face, (13C, 13D and 13E) on the opposing second face, aluminum oxide dielectric is selectively grown on the metal base forming region (12), the protected areas remain as bulk metal (10A, 10B, 10C and 10D). Region (12) can be further developed allowing first face to second face connection and vertical isolation without any drilling.

LED (18) is mounted directly onto the overlying thermal pad (13B) which is plated directly onto the bulk metal (10C) whereby (10A, 10B, 10C and 10D) are sections of the same piece of bulk metal. LED (18) can be mounted using flip-chip or wire-bonding approach as depicted in FIG. 3B abd FIG 3C. The underlying thermal pad (13E) is connected directly to the bulk metal (10C) as well. Advantageously, the LED (18) is thermally connected from first face to the second face via bulk metal (10C).

Since there is no dielectric between the plated copper and the metal base, the through-plane thermal resistance of thermal path is close to the bulk thermal resistance, $R_{substrate}$ estimated at

$R_{substrate} \sim (t/kA)$ °C/W Equation 1

where t is the substrate thickness in meter, k is the material thermal conductivity in W/m-K and A is the area of the heat source in m^2. The thermal conductivity for aluminum alloy ranges from 170W/m-K to 230W/m-K versus the more expensive ceramic at ~30W/m-K and about 0.3 W/m-K for FR4. In the present invention, the base material thickness can range from 150m to 300m in thickness. With reference to Equation 1, the thinner material would have better through-plane thermal conductivity. Since both thermal pad (13B and 13E) are plated with copper (notes: thermal pad are part of copper circuitries), the LED package (100) can be solder-mounted on to a external FR4 or metal core printed circuit board (not shown).

Electrical connections from the first face (13A and 13B) to the second face (13C and 13D) are connected by the same bulk metal (10B and 10C) respectively without drilling. (10B and 10C) are electrically isolated. With selective dielectric on first face, circuit layer (13) provides the circuitries for connecting multiple diodes in array, electrostatic discharge protection circuitry, diode control drivers and other surface mount components (not shown in FIG.2)

In the present embodiment, various types of light shaping design can be over molded onto the substrate as shown in FIG. 3A and FIG 3B. The same light shaping cavity can be pre-stamped or coined onto the Aluminum metal base as shown in FIG. 5. Solder mask (20) can also be applied the said substrate.

The same substrate can be adopted for Prior Art LED emitter light source as shown in FIG. 3E and 3F. 3E substrate has direct connection to the metal base. 3F has an additional dielectric layer for electrical isolation.

The novel substrate design in the present invention is configurable as depicted in FIG. 3. There is no copper or dielectric lamination onto the metal base. The material is RoHS compliant and suitable for high temperature operation exceeding 300°C.

PART II: Pre-stamped Matrix Aluminum Metal Substrate with Matrix Electrical Testing Capability

The manufacturing process steps for the matrix substrate of the present invention are described herein with reference to FIG. 4. FIG. 4 depicts the various views of the matrix substrate pre-stamped material concept. The pre-stamped designs will vary depending on the shape of the LED packaging requirements.

With reference to matrix substrate 100 in FIG. 4, the circle represents the cavity design and conversely will represent one unit device in the matrix substrate for illustration purposes. The sample substrate carries 13 x 13 or a total of 169 devices with either single-layer or multi-layer circuitries. The individual device will be singulated at the end of the manufacturing process before shipping to the end customers. Those skilled in the art will understand that the sample substrate though represented as one matrix with multiple rectangular devices; the substrate can be designed to consist of multiple matrices with patterned shape; for example, a STAR or round shape or any odd shape design to suit the end product industrial design.

Shown in FIG. 4 is base layer 100 formed from a material having good thermal conductivity as described in the present invention. The same pre-stamped concept is applicable to equivalent flat base substrate for matrix manufacturing.

In the preferred embodiment, the base material is Aluminum Alloy. However, other materials having similar properties may also be used. In the preferred embodiment, a

thin layer of dielectric is selectively added to the surface of the aluminum in areas that requires electrical isolation. Those skilled in the art will understand that the dielectric may simply be a laminated ceramic resin or anodic coating grown using the hard anodization process. Circuitry of copper traces may be formed either by etching away the laminated copper foil or selectively plated using the additive process. In the preferred embodiment (106), copper is selectively plated on dielectric areas for electrical isolation and directly on aluminum surface on heat source location to maximize thermal conduction. Besides copper, other types of electrically conductive material like silver ink may also be used.

Substrate (100) has pre-stamped cut-outs (103) and pre-stamped v-cut straight lines (104). 103 and 104 define the basis of the present invention. 103 need not be a rectangular shaped cut-out. 103 can be different depending on the patterned shape layout.

With the same stamping mould, (105) can be created. If used as a reflector cup, reflective material can be applied to enhance reflectivity.

The Design-for-Testability features can be incorporated to allow matrix testing. (107 are added circuitries within the device. In the example of matrix LED substrate, (107 can be just a common cathode bus for all devices.

The present invention is specifically adapted to and has been described in connection with a flat plate metal base substrate but is not so limited; the invention can, in fact, be applied to substantially any substrate made of different material particularly hybrid metal substrate, ceramic based substrate, BT epoxy based substrate, Fibre Glass printed circuit based substrate or metal finned heatsink with a flat interface for electrical connectivity.

It is understood that the above-described embodiments are illustrative of only a few of the many possible specific embodiments, which can represent applications of the invention. The same substrate can be used for power electronic devices; multi-chip module applications besides light source application. Numerous and varied other arrangements can be made by those skilled in the art without departing from the spirit and scope of the invention.

CLAIMS

1. A high power light source on a thermally efficient metal substrate package, the substrate package (100) comprising:
a metal base (10) having opposed first and second faces (13A, 13B and 13C, 13D, 13E),
a plurality of electrical circuitries mounted on the first and second faces (13A, 13B and 13C, 13D, 13E) and insulated from the substrate;
at least one light source mounted on one of the first and the second electrical circuitries (13A-E) wherein the electrodes (11A, 11B) of the light source are connected to the electrical circuitries (13A-E); and the light source is encapsulated in a molding of material forming the light shaping surface and mechanical protecting surface for the light source.

2. A light source as claimed in claim 1, wherein the metal base (10) is made of aluminium.

3. A light source as claimed in claim 1 or 2, wherein the electrodes (11A, 11B) are connected to the electrical circuitries (13A, 13B, 13C) by wire bonding or flip-chip mounting.

4. A light source as claimed in any one of the claims 1 to 3, wherein the LED (18) is mounted on the substrate (100) in a cavity (31,32) designed for light shaping purposes.

5. A light source on a thermally efficient metal substrate package (100) as claimed in any one of claims 1 to 4, wherein the first face of the substrate (100) is mountable with a LED emitter (18) or another device; and at least one isolated terminal for other electronic component integration on the substrate wherein the LED electrodes (11A, 11B) are electrically connected to conductive traces of the electrical circuitries (13A-E).

6. A light source on a thermally efficient metal substrate package (100) as claimed in claim 4 or 5, wherein the stamp-outs (103) and scoring lines (104) are designed to allow singulation without sawing process.

7. A method of manufacturing multiple similar light sources on metal substrate (100) comprising:

a substrate (100) format having a plurality of matrix of repeated circuitries, one face of the substrate format for single layer application, the matrix of repeated circuitries each having a first face and a second face with electrical and thermal interconnects between the first and second faces for multi-layer application;

a plurality of three-dimensional surface formations in said first and second faces;

a plurality of electrical interconnects (107) between the repeated circuitries; and

a plurality of stamp-outs (103) and scoring lines (104) for unit device singulation purposes.

8. A method as claimed in claim 7, wherein the substrate format is designed in a matrix for high volume assembly whereby once fully assembled, the substrate (100) is capable of being over-molded or encapsulated and subsequently electrically tested, and being burned-in in the matrix format using the electrical interconnects (107) between the repeated circuitries.

9. A method as claimed in claim 7 or 8, wherein the matrix (107) of repeated circuitries each having the same structure as the substrate claimed in claim 1.

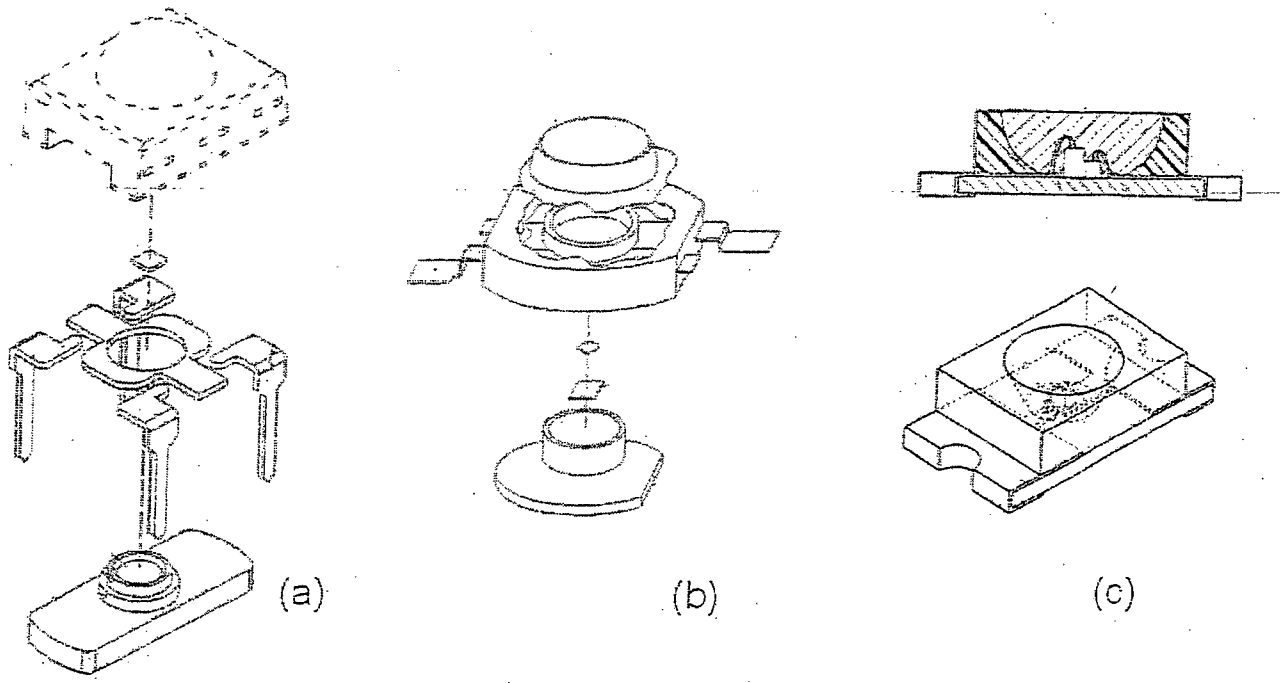


FIGURE 1

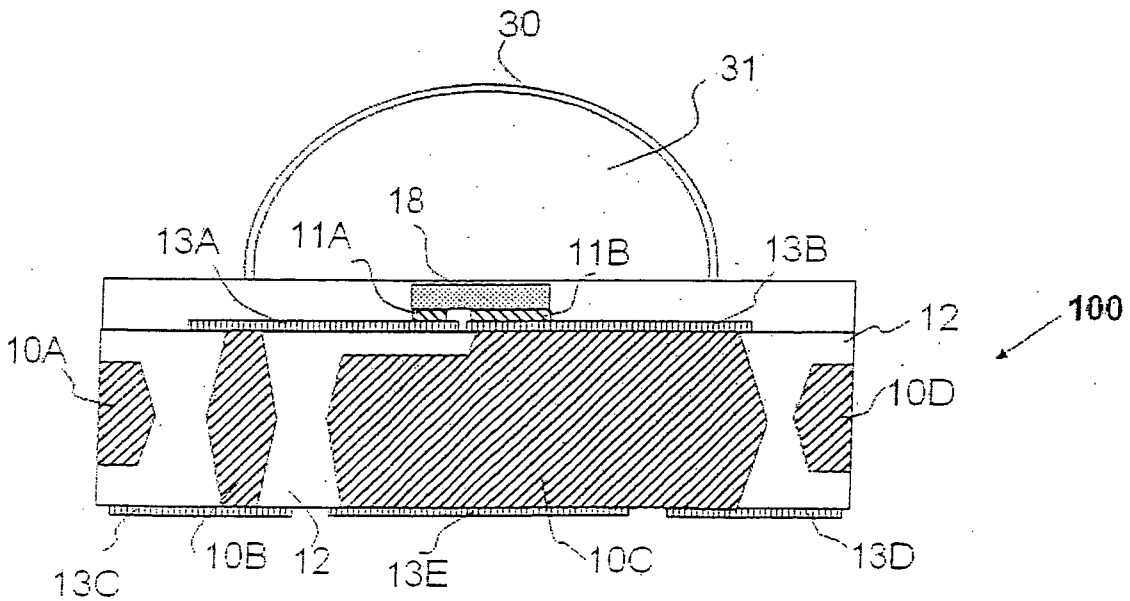
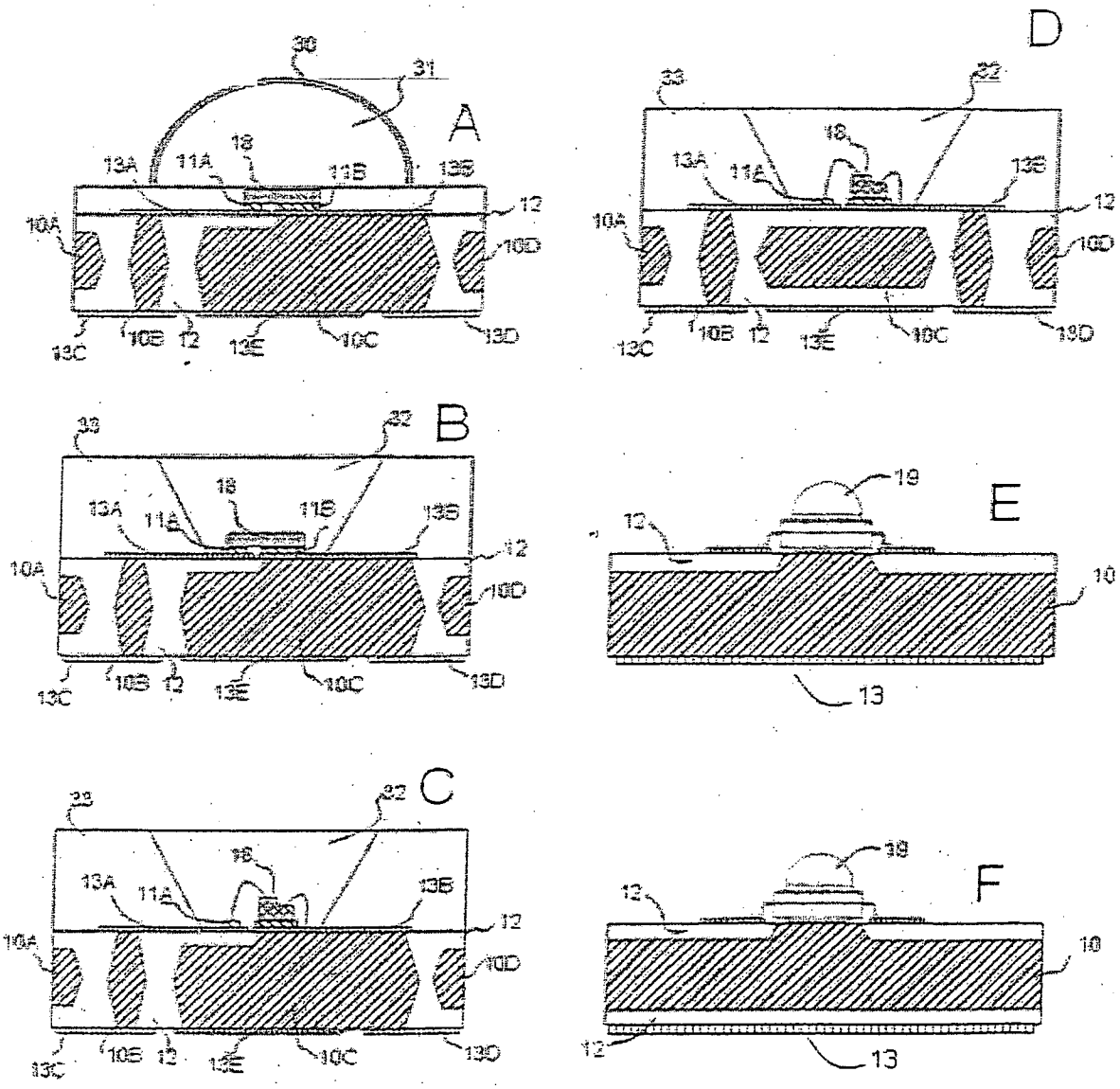


FIGURE 2


A
B
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F
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18
11A
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FIGURE 3

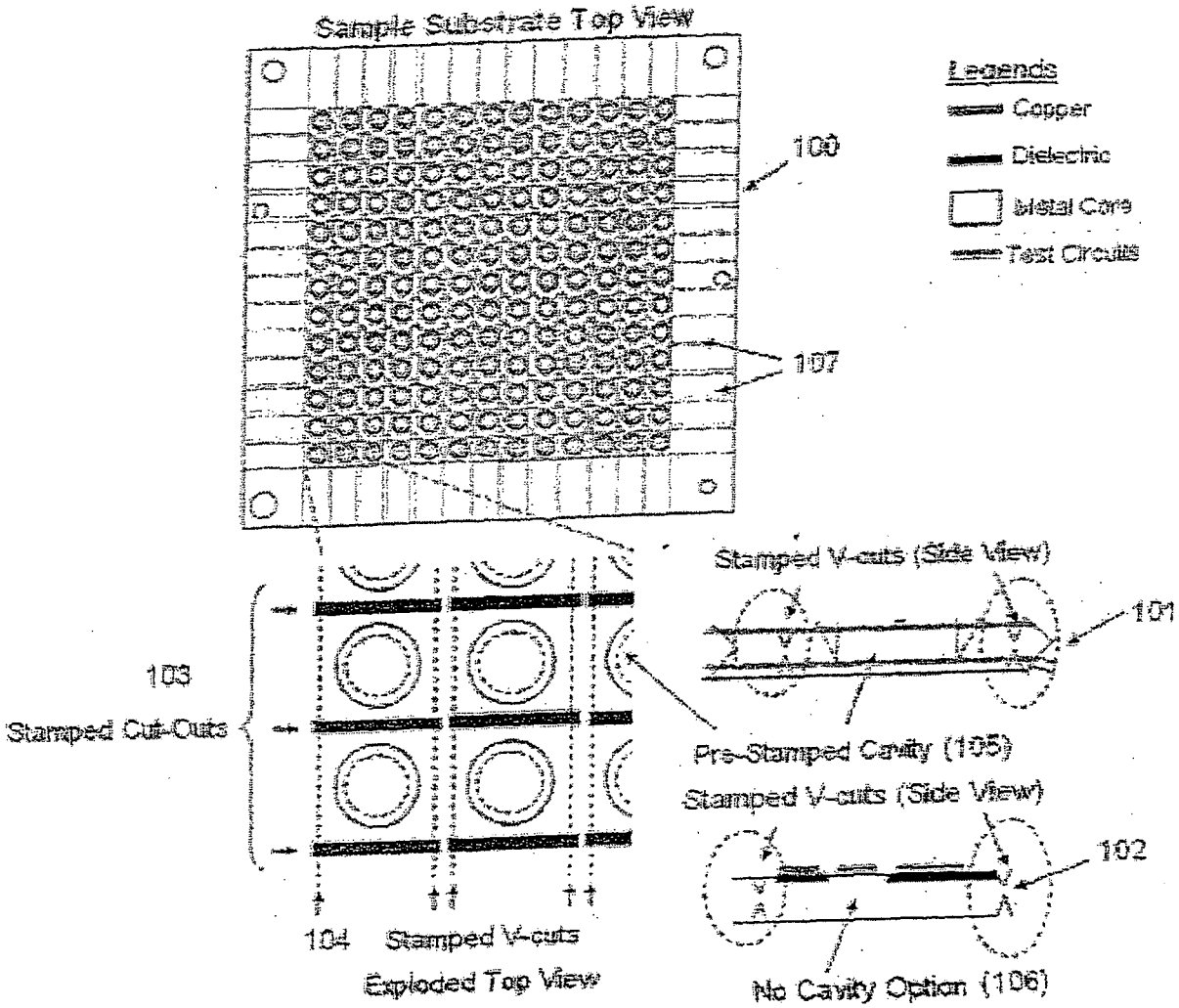

FIGURE 4

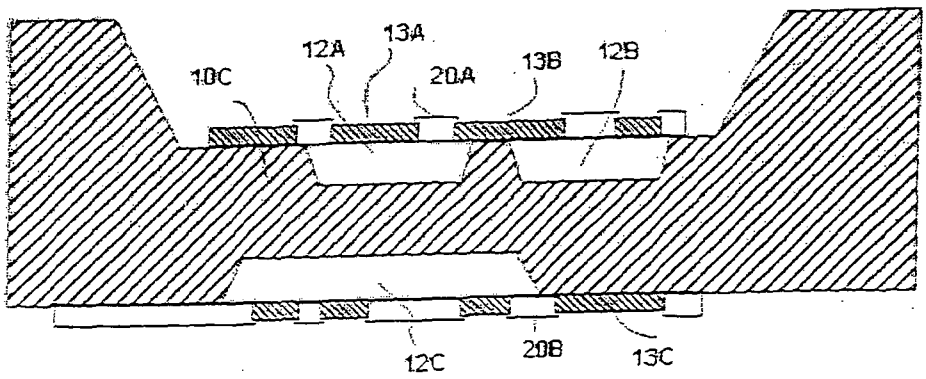

FIGURE 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/MY2008/000027

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L33/00

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)
H01S H01L

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 2007/221928 A1 (LEE YOUNG KI [KR] ET AL) 27 September 2007 (2007-09-27) figure 2	1-5
X	& KR 100 703 218 B1 (SAMSUNG ELECTRO MECH [KR]) 28 March 2007 (2007-03-28) figure 2	1-5
X	KYUHO SHIN ET AL: "Chip-on-ACB (anodized circuit board) package for high power light-emitting diode" JOURNAL OF MICROELECTRONICS AND ELECTRONIC PACKAGING, IMAPS, WASHINGTON, 1 January 2006 (2006-01-01), pages 67-72, XP009103385 ISSN: 1551-4897 figure 2	1-5

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[X] Further documents are listed in the continuation of Box C.

[X] 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 document 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 another 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
31 July 2008	18/09/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jobst, Bernhard

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/MY2008/000027

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	KIM K M ET AL: "Aluminium-based packaging platform for LED using selectively anodising method" ELECTRONICS LETTERS IET UK, vol. 44, no. 1, 3 January 2008 (2008-01-03), pages 24-25, XP009103483 ISSN: 0013-5194 the whole document	1-5
P,X	US 2007/080360 A1 (MIRSKY URL [IL] ET AL) 12 April 2007 (2007-04-12) figure 2	1-5

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/MY2008/000027

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-5

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5

Claims 1-5 relate to a light source comprising a particular structure for mounting and connecting the chip.

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2. claims: 6-9

Claims 6-9 relate to a method of forming individual light sources out of a plurality of structures formed on a substrate.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/MY2008/000027

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007221928 A1	27-09-2007	CN 101038949 A	19-09-2007
		JP 2007251167 A	27-09-2007
KR 100703218 B1	28-03-2007	CN 101038949 A	19-09-2007
		JP 2007251167 A	27-09-2007
		US 2007221928 A1	27-09-2007
US 2007080360 A1	12-04-2007	NONE	