LIGHT SOURCE WITH GLASS HOUSING

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ABSTRACT
A light source comprising at least one light-emitting diode (2), which emits light, and a housing (5) arranged to receive at least a portion of said light is provided. The housing (5) comprises a translucent glass material and is provided with at least one recess (4) that comprises positioning and orientating means. The at least one light-emitting diode (2) is arranged in said at least one recess (4), is positioned and orientated by said positioning and orientating means and is bonded to said housing. By utilizing a fully inorganic approach for the housing, the temperature stability of the light source is improved.
LIGHT SOURCE WITH GLASS HOUSING

TECHNICAL FIELD

[0001] The present invention relates to a light source comprising at least one light-emitting diode, which emits light, and a housing arranged to receive at least a portion of said light. The present invention further relates to a method for the manufacture of such a light source.

TECHNICAL BACKGROUND

[0002] Semiconductor light-emitting devices, such as light-emitting diodes (LEDs) and laser diodes (LDs), are among the most efficient and robust light sources currently available.

[0003] Light extraction is a key issue for light emitting devices. A common problem of semiconductor light-emitting devices is that the efficiency with which light may be extracted from the device is reduced due to internal reflection in the interface between the device and the surroundings, followed by re-absorption of the reflected light in the device. The internal reflection is due to that the refractive index of the device materials is higher than the refractive index of the material in which the device is packaged or encapsulated.

[0004] For high efficient light extraction, it is advantageous if the light extracting materials are in direct contact with the light-emitting device. However, in high power applications, where single solid-state light emitting devices with an effect of up to 3 Watts per square mm or arrays of such devices, with a total effect of up to 100 Watts or more, a lot of heat is dissipated from the light emitting devices. Temperatures of up to 250°C are easily reached for such high power application.

[0005] Thus, for high-power applications, a heat resistant encapsulation has to be used, and it would be advantageous to use an inorganic approach, as inorganic materials may be chosen that have very high temperature resistance.

[0006] JP-2003179270-A describes a semiconductor light-emitting element coated directly with a translucent coating material made of poly methylmethacrylate or ceramic and that is heat resistant.

[0007] However, the processing temperature for connecting the coating material and the light emitting element must be low, e.g. lower than ~350°C, or otherwise, the n/p-junctions in the light emitting element will be damaged.

[0008] For coatings/encapsulations of inorganic materials, it would be advantageous to be able to use higher temperatures, for example to increase the range of different materials which can be used, and in steps of attaching other components, such as for example lenses, to the encapsulation.

[0009] However, substrates and circuitry on which light-emitting semiconductor devices are arranged are often heat sensitive. Thus, it would be advantageous with a device that allows for high-temperature processing of the encapsulation without damaging the substrate and/or circuitry.

[0010] For high-intensity applications, it would also be advantageous to be able to easily arrange several semiconductor light-emitting devices under the same encapsulation to, for example, reduce the size of the device and to improve color mixing.

SUMMARY OF THE INVENTION

[0011] It is an object of the present invention to at least partly overcome the problems with the prior art, and to provide a LED-based light source that is temperature stable wherein steps in the manufacturing may involve temperatures higher than the breakdown temperature of the LEDs. Thus, in a first aspect, the present invention relates to a light source comprising at least one light-emitting diode, which emits light, and a housing arranged to receive at least a portion of said light. The housing comprises a translucent glass material and is provided with at least one recess that comprises positioning and orientating means. In the light source, the at least one light-emitting diode is arranged in the at least one recess, is positioned and orientated by the positioning and orientating means and is bonded to the housing.

[0012] An advantage of a light source of the present invention is that the crystalline substrate of the LED(s) is bonded to the glass housing. Thus, no organic adhesives are needed, and the light source will be temperature stable. Further, in the present invention, a LED is arranged in preformed recesses in the housing. As the step of forming the housing is separate from the step of bonding the LEDs to the housing, the processing temperatures for forming the housing may be higher than the breakdown temperature of the LEDs, as long as the temperature at which the LED is bonded to the housing is below this breakdown temperature. Thus, the processing temperature of the housing is independent from the breakdown temperature of the LEDs. In embodiments of the present invention, the walls of the at least one recess may constitute the positioning and orientating means.

[0013] Thus, each LED comprised in the light source will be positioned and orientated by the walls of the recess that it is arranged in. In embodiments of the present invention, the housing comprises a luminescent material.

[0014] A luminescent material may be used to convert the color of the light emitted by a LED into a different, converted color. An advantage with this embodiment is that luminescent materials increase the possible choices of color provided by the light source. In embodiments of the present invention, a bonding material, being a glass material, is arranged in the at least one recess, between the housing and the at least one light-emitting diode, to bond the at least one light-emitting diode to the housing.

[0015] An advantage of this embodiment is that glassy bonding materials may be chosen having a temperature at which the bonding of the LED is convenient and effective that is lower than the corresponding temperature of the housing material. This increases the range of housing materials that are suitable for use in the present invention. In further embodiments of the present invention, the above-mentioned glassy bonding material, which binds the light-emitting diode to the housing, may comprise a luminescent material.

[0016] An advantage with this embodiment is that color conversion of the light emitted by an LED being bonded to the housing by this bonding material is provided by the bonding material. This color conversion may be used in combination with color conversion provided by luminescent material in the housing material, or on its own. In embodiments of the present invention, a first light-emitting diode is arranged in a first recess in the housing and a second light-emitting diode is arranged in a second recess of the housing.

[0017] An advantage of this embodiment is that by positioning separate LEDs in separate recesses, a very exact positioning and orientation of each LED is allowed, being desired when the LEDs of the present light source to be arranged on and connected to a driving circuitry. In further embodiments of the present invention, a first bonding material comprising a first luminescent material may be arranged in a first recess of
the housing between a first light-emitting diode and the housing, and a second bonding material comprising a second luminescent material may be arranged in a second recess, between a second light-emitting diode and the housing.

[0022] These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing currently preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 illustrates a cross-section of one embodiment of a lighting device according to the present invention.

[0024] FIGS. 2, a-f, outline a method for the manufacture of a lighting device according to the present invention

PREFERRED EMBODIMENTS OF THE INVENTION

[0025] One exemplary embodiment of the present invention, as shown in FIG. 1, comprises a sub-mount 1 provided with a circuitry. An array of light-emitting diodes (LEDs) 2, 2' is arranged on the circuitry, and each LED of the array is separately connected to the circuitry by metal bumps 3 at pre-determined positions.

[0026] Each LED 2, 2' is arranged in a separate recess 4, 4' in a housing 5 of a translucent glass material, and the location and the orientation of each LED 2, 2' is determined by the walls of the corresponding recess 4, 4'.

[0027] Each LED comprises the active layers arranged on a crystalline substrate, through which light is emitted when the LEDs are active. The substrate is physically bonded to the housing in order to optically connect the LED with the housing.

[0028] Furthermore, a transparent hemisphere 6 is arranged on the housing 5 to spread the light emitted by the device. A preferred method for the manufacture of a light source of the present invention is outlined in FIGS. 2, a-f.

[0029] A translucent glass housing 5 having a plurality of recesses 4, 4' is provided. (FIG. 2a).

[0030] Then, a LED 2, 2' is arranged in each recess 4, 4' at a temperature between the glass temperature and the softening temperature of the housing material (thermo-compression), for example in the range from 200° C. to 400° C., preferably from 250° C. to 350° C. (depending on the housing material), to obtain good contact between contact layer material and LED. The thus formed housing-LED assembly is cooled down to a temperature where bonding of the LED to the housing via the contact layer is obtained (FIGS. 2c-d).

[0031] Optionally, a glassy contact layer material 8, 8' is arranged in the recesses 4, 4', typically in the form of a powder or sheets or the like. The contact layer material is then melted in the recess to become compacted and degassed. Then, at a temperature between the glass temperature and the softening temperature of the contact layer material, the LEDs 2, 2' are arranged on the contact layer material (thermo-compression). Upon cooling, the LEDs become bonded to the contact layer material, and the contact layer material becomes bonded to the housing (FIGS. 2b-d).

[0032] The housing-LED assembly is then arranged on a sub-mount 1 to bring the connectors of the LEDs in contact with metal bumps 3 arranged on a circuitry 7 arranged on the sub-mount (FIG. 2e). The housing-LED assembly and the sub-mount are thermo-compressed at a temperature high enough to effect binding of the LEDs to the circuitry, but still at a temperature low enough that the sub-mount and circuitry are not damaged (FIG. 2f).

[0033] The described method allows for the formation of the housing in processes involving temperatures at which the
circuitry and the sub-mount would be damaged. For example, the housing may be molded at temperatures well above the melting temperature for the housing material (typically in the range of 300-1600°C, temperatures where the circuitry and/or sub-mount would be damaged).

This allows for the use of glass materials to be used as housing materials.

It is to be understood that the above-mentioned preferred embodiments are provided for illustrative purposes only. Those skilled in the art will realize that variations of the present invention are possible, which still fall under the scope of the claims. The sub-mount may be any substrate suitable on which a circuitry may be arranged. Commonly used substrates are well known in the art and include, for instance, silicon substrates and aluminum nitride substrates.

The circuitry comprises a pattern of an electrically conducting material, such as metallic or non-metallic electrically conducting compounds. In FIG. 2, the circuitry is arranged to connect all LEDs in series. However, other circuitry configurations are possible, such as parallel connection or separate connection of each LED.

Metal bumps may be used to connect the LEDs to the circuitry, and comprises an electrically conducting material, such as a metal, for example gold or tin. They are arranged on the circuitry in a pattern, which corresponds to the positioning of the LEDs in the housing. Thus, after the LEDs are arranged in the housing, the location of the contact pads of the LEDs fits on the pattern of the metal bumps. Light-emitting diodes suitable for use with the present invention include LEDs capable of emitting light in the any wavelength or wavelength range from ultra-violet to infrared light.

As used herein, the term “light-emitting diodes” refers to diodes emitting light in any wavelength interval from UV-light to infrared light, and includes laser diodes.

Examples of LEDs suitable for use in the present invention include those constructed by growing n/p light-emitting layers on a crystalline substrate, such as sapphire (single crystal alumina), to obtain a LED having a flat profile with the connectors to both the cathode and the anode of the diode located on the side opposite to the substrate. Accordingly, no wire bonding is located on the substrate side of the LED, i.e., the side of the LED mainly emitting light (commonly known as “flip-chip”-LEDs). Such LEDs may be mounted in the housing with the substrate side bonded to the housing, such that the connectors are easily accessible.

In preferred embodiments of the present invention, the LEDs are blue or UV emitting diodes. One advantage is that blue/UV light easily can be converted into light of other colors by luminescent compounds.

High-power LEDs, with an effect of 3 Watts per square mm or more, may advantageously be used in the present invention. The housing of the present invention is made of a translucent glass material. As used herein, the term “translucent” is taken to also include “transparent”, in the meaning that a transparent material is a translucent material. The glass material may for example be chalcogenide glass, lead silicate glass, tellurite glass, bismuth glass, borosilicate glass, etc and mixtures of such glasses. Glass materials suitable for use in the present invention is highly heat resistant and can stand the high temperatures dissipated by high-power LEDs and used when the optional contact layer material is filled into the recesses. Preferably, the housing material is resistant to even higher temperatures, such as the temperature used in optional steps of connecting the housing to a ceramic or glassy light extracting body, such as a lens.

The architecture of the light source according to the present embodiment makes it suitable, even if not limited, to use housing materials having a melting temperature higher than the break-down temperature of the LEDs to be arranged in the housing, such as a melting temperature of 350°C.

Suitably, the housing material has a refractive index which is equal with or higher than the refractive index of the light emitting diode, for example higher than 1.7. However glass materials having a refractive index lower than 1.7 may also be used.

The housing of the present invention has several functions. One function is to arrange the LEDs in desired positions and orientations before the LED-housing assembly is arranged on the sub-mount and the LEDs are connected to the circuitry.

Preferably, a recess in the housing is sized such that a LED easily fits in the recess, but becomes arranged in a desired position and orientation to also be properly connected to the circuitry. This is especially advantageous when an array of LEDs is arranged in individual recesses in a housing. All the LEDs becomes properly located and aligned in the housing to fit on a pre-produced circuitry.

The housing, with its recesses, may be pre-manufactured separate from the manufacturing of the light-source of the invention. Thus, this pre-manufacturing is not dependent on the temperature limits set by the break-down temperature of the LEDs to be arranged in the housing, and allows the use of housing materials having a high melting temperature, such as for example essentially higher than 350°C. Typically, LEDs break down when exposed to temperatures higher than 350°C for more than a few minutes.

In the case of bonding LEDs directly to the housing, without use of an optional contact layer (see below), this bonding may advantageously be performed at a temperature between the glass temperature (Tg) and the softening temperature (Tf) of the housing material by use of thermo-compression. This temperature may for example be in the range of from 200 to 400°C, preferably below 350°C. This bonding temperature is typically essentially below the melting temperature of the housing material. Upon cooling, an efficient physical binding and optical connection is achieved between the LED and the housing.

In the embodiment shown in FIGS. 1 and 2, each LED is arranged in a separate recess and the walls of the recesses constitutes the positioning and orientating means for each LED. However, in other embodiments of the present invention, more than one LED may be arranged in one recess. In such cases, the positioning and orientating means may, for example, be constituted by elements which prevents LEDs from moving or rotating in the plane of the LEDs, but which means does not form walls separating the recess into a plurality of recesses.

Another, optional, function of the housing is to convert the color of the light received by the housing into a desired color. In such instances, the housing material may comprise a luminescent compound, or combinations of two or more luminescent compound.

As used herein, the term “luminescent material” refers to both fluorescent and phosphorescent materials, which absorbs light of a wavelength or wavelength interval and emits light of another wavelength or wavelength interval.
Luminescent compounds suitable for use in the present invention include, but are not limited to, yttrium-aluminum-garnet (YAG) doped with cerium (YAG:Ce), praseodymium (YAG:Pr), europium (YAG:Eu) or combinations of these dopants (such as for example YAG:Ce, Eu). Other luminescent compounds will be apparent to those skilled in the art.

For example, YAG:Ce may be used in a light source for providing white light. The YAG:Ce converts blue light into yellow light, and this yellow light, together with residual, non-converted blue light, provides a white light.

The luminescent compound may for example be mixed into the bulk glass material before the manufacture of the housing element. In some embodiments of the present invention, LEDs are bonded to the housing via a contact layer 8, which optically connects and physically binds a LED to the housing. Moreover, the contact layer acts as a light-extracting layer, extracting the light out of the light-emitting diode into the housing.

The contact layer material may be a translucent, especially transparent, glass material, for example chosen from the group comprising chalcosilicone glass, lead silicate glass, tellurite glass, bismuth glass, etc.

A glass material is advantageously due to the good optical properties of glass. Other contact layer materials suitable for use in the present invention include aluminum phosphate and aluminum oxide, as well as mixtures thereof.

Preferably, the contact layer material has a refractive index in the range from at least 1.7 up to 2.3, or even higher.

The thickness of the contact layer can vary in the range of from less than 1 μm to higher than 150 μm.

Preferably, the contact layer material has a glass temperature (T_g), softening temperature (T_s) and melting temperature (T_m) that is lower than the corresponding temperatures for the housing material.

Typically, the contact material is dispensed in the recesses of the housing in the form of particles (powder), sheets or the like. Thereafter, the contact material is melted in the recess to become more dense and to remove air in the material, i.e. the housing and the recesses may be used as crucibles to melt the material. This melting (preparation of the contact material) may be performed at temperatures essentially higher than the break-down temperature for LEDs. Typically, the melting temperature for suitable contact materials is above 350 °C. However, after proper melting and preparation of the contact material, LEDs may be bonded to the housing via the contact layer at a temperature between the glass temperature and the softening temperature of the contact glass material (thermo-compression), preferably from 200 to 400 °C, more preferably at a temperature below 350 °C. Upon cooling, an efficient physical binding and optical connection is achieved between the LED and the contact material, as well as between the contact material and the housing material.

The contact layer material may contain luminescent compounds to convert the color of light emitted by the LED into a desired color, for example for converting blue light into green or red light, or for converting UV-light into blue, green or red light. Such luminescent compounds suitable for incorporation into the contact layer material are known to those skilled in the art. Examples of luminescent compounds suitable for converting blue light into red light include, but are not limited to luminescent silicon nitride compounds, such as Sr_2Si_N doped with europium, aluminum or oxygen or (Sr_x, Ba_y)Si_N doped with europium, with varying Ba-concentration (varying X).

Examples of luminescent compounds suitable for converting blue light into green light include, but are not limited to Sr_2Si_N doped with europium and LuAG (lutetium-aluminum-garnet) doped with cerium. Other luminescent compounds will be apparent to those skilled in the art.

The luminescent compounds may be mixed in the bulk contact material before dispensing this into the individual recesses, or may be arranged separately in the recesses before or after, preferably before, dispensing the contact material in the recesses.

In embodiments of the present invention, comprising several LEDs arranged in separate recesses, different contact materials, e.g. comprising different luminescent materials, may be arranged in different recesses.

Thus, an array of LEDs of the same type, for example UV emitting diodes may be arranged in the housing, where the light emitted from different LEDs are converted into different colors by different luminescent materials in the contact layer, for example into blue, green and red light respectively to provide a RGB-array. Such an array can be used to provide white light. Further, when separate LEDs can be driven independently, a color variable light source is provided.

Alternatively, to form a RGB-array, an array of blue and green LEDs may be arranged in a housing, wherein the light from some of the blue or green LEDs may be converted by a blue-to-red or green-to-red luminescent material, respectively, in the contacting layer for some of the LEDs. Other combinations of LEDs and luminescent compounds in the contact material are also possible and comprised in the scope of the claims.

Various combinations of materials for the contact layer and the housing are also possible, as will be apparent to those skilled in the art.

For example, an array of LEDs can be provided with contact materials comprising luminescent materials to provide for example an RGB-array, which can provide white or color variable light. In such a case, the housing does not need to comprise any phosphor material to further convert the color of the light.

In another example, an array of blue LEDs may be bonded to the housing, without the utilization of contact materials comprising luminescent material. However, the housing may comprise a luminescent compound, for example YAG:Ce, to convert the blue light into white light. Furthermore, other optical elements may be used in combination with the device of the present invention. For example, collimating, focusing or dispersing lenses may be arranged on the housing to alter the direction of the light emitted by the LEDs. A specular reflector arranged on the substrate around the housing to collimate/focus the emitted light may also be used. Other optical elements suitable will be apparent to those skilled in the art and are comprised in the scope of the appended claims.

Optical elements may be bonded to the housing, on the side opposite of the recesses, and may be arranged on the housing before arranging the LEDs in the recesses. This allows the bonding of the optical element to the housing to proceed at temperatures to be used at which otherwise would damage the LEDs.
1. A light source comprising at least one light-emitting diode which, in operation, emits light, and a housing arranged to receive at least a portion of said light, characterized in that, said housing comprises a translucent glass material and is provided with at least one recess that comprises positioning and orientating means, said at least one light-emitting diode is arranged in said at least one recess, is positioned and orientated by said positioning and orientating means and is bonded to said housing.

2. A light source according to claim 1, wherein the walls of said at least one recess constitutes said positioning and orientating means.

3. A light source according to claim 1, wherein said housing comprises a luminescent material.

4. A light source according to claim 1, wherein a bonding material is arranged in said at least one recess between said at least one light-emitting diode to bond said at least one light-emitting diode to said housing and said bonding material is a glass material.

5. A light source according to claim 4, wherein said bonding material comprises a luminescent material.

6. A light source according to claim 1, wherein a first light-emitting diode is arranged in a first recess and a second light-emitting diode is arranged in a second recess.

7. A light source according to claim 6, wherein a first bonding material comprising a first luminescent material is arranged in said first recess, between said first light-emitting diode and said housing, and a second bonding material comprising a second luminescent material is arranged in said second recess, between said second light-emitting diode and said housing.

8. A light source according to claim 1, wherein an optical element is bonded to said housing and arranged to receive at least a portion of said light.

9. A light source according to claim 1, further comprising a substrate on which a circuitry is arranged, and wherein said at least one light-emitting diode is arranged on and connected to said circuitry.

10. A method for the manufacture of a light source, comprising:
providing at least one light-emitting diode;
providing a housing having at least one recess and diode positioning and orientating means arranged in said recess, said housing comprising a translucent glass material;
arrainging said at least one light-emitting diode in said recess, such that said light-emitting diode is positioned and orientated by said positioning and orientating means, said at least one light-emitting diode is bonded to said housing, and said housing receives, in operation, at least a portion of light emitted by said at least one light-emitting diode.

11. A method according to claim 10, wherein said light-emitting diode is bonded to said housing at a temperature between the glass temperature and the softening temperature of said translucent glass material.

12. A method according to claim 11, wherein said temperature between the glass temperature and the softening temperature of said translucent glass material comprised in said housing is from 200 to 400°C.

13. A method according to claim 10, comprising arranging a contact glass material in said at least one recess, and at a temperature between the glass temperature and the softening temperature of said contact glass material, arranging said at least one light-emitting diode on said contact glass material.

14. A method according to claim 13, wherein said temperature between the glass temperature and the softening temperature of said contact glass material is from 200 to 400°C.

15. A method according to claim 10, further comprising connecting said at least one light-emitting diode being bonded to said housing, to a circuitry.

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