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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 December 2010 (16.12.2010)

PCT

(10) International Publication Number
WO 2010/143114 A1

(51) International Patent Classification:
H01L 33/44 (2010.01)

(21) International Application Number:
PCT/IB2010/052507

(22) International Filing Date:
7 June 2010 (07.06.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09162472.6 11 June 2009 (11.06.2009) EP

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

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

Declarations under Rule 4.17:

[Continued on next page]

(54) Title: LED ILLUMINATION DEVICE

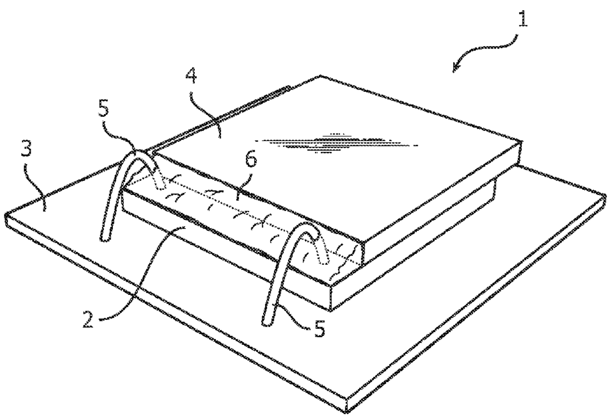

FIG. 1a

(57) Abstract: The invention relates to an illumination device comprising a semiconductor light-emitting element (2) having a light out-coupling side; a wavelength converting member (4) arranged on a region of said light out-coupling side of the semiconductor light-emitting element and not covering another region of said light out-coupling side; an electrically conductive member (5) contacting said light out-coupling side of the semiconductor light- emitting element at said region of the light out-coupling side not covered by the wavelength converting member; and a light redirecting and/or absorbing member (6) arranged on said light out-coupling side of the semiconductor light-emitting element at the region thereof not covered by the wavelength converting member and in direct or indirect contact with a lateral side of said wavelength converting member, such that, in operation, light emitted via the light out-coupling side of the semiconductor light-emitting element at the region thereof not covered by the wavelength converting member is absorbed or redirected by the light redirecting and/or absorbing member. The illumination device according to the invention produces light of more homogeneous color and/or improved color purity.

WO 2010/143114 A1

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

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

Illumination device

FIELD OF THE INVENTION

The present invention relates to a wavelength converting member for use in LED based illumination devices.

BACKGROUND OF THE INVENTION

Light-emitting diode (LED) based illumination devices are increasingly used for a wide variety of lighting and signaling applications. LEDs offer advantages over traditional light sources, such as incandescent and fluorescent lamps, including long lifetime, high lumen efficacy, low operating voltage and fast modulation of lumen output.

Efficient high-power LEDs are often based on blue light emitting InGaN materials. To produce an LED based illumination device having a desired color (e.g., white) output, a suitable wavelength converting material, commonly known as a phosphor, may be used which converts part of the light emitted by the LED into light of longer wavelengths so as to produce a combination of light having desired spectral characteristics. The phosphor may for example be embedded in an organic encapsulant material, such as epoxy, applied on top of the LED, or it may be pre-formed into a ceramic self-supporting layer (without the use of a binder) which may be applied on the LED. Advantageously, a ceramic phosphor layer is more robust and less temperature sensitive than conventional organic phosphor layers.

A ceramic phosphor layer may be easily applied in flip-chip LED based illumination devices, in which both positive and negative electrical contacts are arranged on one side of the LED (where there is no light emission). However, with vertical LEDs bonded via electrical contacts on opposing sides of the LED, a pre-formed, solid ceramic phosphor cannot be readily used since one of the electrical contacts would obstruct the mounting of the ceramic layer. In order to solve this problem US 2008/0232420 presents an LED with a functional element (e.g. a ceramic phosphor layer) mounted on a light out-coupling side of the LED, which functional element comprises provisions, such as slits or holes, for electrically contacting the LED on the light out-coupling side. The slits or holes allow a defined amount of LED light to escape the phosphor unconverted, the output light thus comprising both converted and unconverted light. However, although leakage of unconverted light may be advantageous, in some instances it may be desirable to achieve a more homogeneous color output and with a better spectral purity.

Hence, despite the solution proposed in US 2008/0232420, there remains a need in the art for improved LED-phosphor based arrangements.

SUMMARY OF THE INVENTION

It is an object of the present invention to at least partly overcome the above problem, and to provide a wavelength converting member which allows the use of a wavelength converting ceramic plate with vertical LEDs, while providing improved light emission.

In a first aspect, the invention relates to an illumination device comprising:

- a semiconductor light-emitting element having a light out-coupling side;
- a wavelength converting member arranged on a region of said light out-coupling side of the semiconductor light-emitting element such that another region of said light out-coupling side of the semiconductor light-emitting element is not covered by said wavelength converting member;
- an electrically conductive member contacting, directly or indirectly, said light out-coupling side of the semiconductor light-emitting element at said region of the light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting member; and
- a light redirecting and/or absorbing member arranged on said light out-coupling side of the semiconductor light-emitting element at the region thereof not covered by the wavelength converting member and in direct or indirect contact with a lateral side of said wavelength converting member, such that, in operation, light emitted via the light out-coupling side of the semiconductor light-emitting element at the region thereof not covered by the wavelength converting member is absorbed or redirected by the light redirecting and/or absorbing member.

The light redirecting and/or absorbing member may thus be arranged at the region of the light out-coupling side of the semiconductor light-emitting element that is contacted by said electrically conductive member.

The light redirecting and/or absorbing member serves to prevent unconverted light emitted by the semiconductor light-emitting element at the area around the bond wire connection from escaping the illumination device, by absorbing and/or redirecting said light. As a result, the illumination device according to the invention produces light of more homogeneous color and/or of improved color purity, with little or no leakage of unconverted light.

Preferably, the semiconductor light-emitting element may be a light-emitting diode (LED).

In embodiments of the invention, the wavelength converting member comprises a ceramic body, typically a ceramic plate, the advantages of which include mechanical robustness, improved temperature tolerance, and high light conversion efficiency. Since such a ceramic plate, which is pre-formed, may leave a relatively large region of the semiconductor light-emitting element uncovered by it, the use of a light redirecting and/or absorbing member as described herein is particularly advantageous with ceramic phosphor plates.

Typically, in operation, the semiconductor light-emitting element may emit light of a first wavelength range and the wavelength converting member may emit light of a second wavelength range. As used herein, said light of a first wavelength range is also referred to as unconverted light, and said light of a second wavelength range is also referred to as converted light. In embodiments of the invention, the ratio of the intensity of light of said first wavelength range emitted by the illumination device to the intensity of light of said second wavelength range emitted by the illumination device may be less than 1:50, preferably less than 1:100, more preferably less than 1:500 and most preferably less than 1:1000. These ratios refer to the light emitted by the illumination device as a whole, which includes light of the second wavelength range emitted by the wavelength converting member and light of the first wavelength range emitted by the LED which has escaped both absorption and conversion and thus is out-coupled from the illumination device. The less unconverted light is emitted by the illumination device (relative to the converted light emitted), the higher may be the color purity. In some applications, a high color purity may be desirable, whereas in other applications, a more homogeneous color output may be the main purpose.

Leakage of unconverted light may be reduced in various ways. For example, the light redirecting and/or absorbing member may absorb light of said first wavelength range emitted via the region of the light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting element. Thus, the color purity of the light emitted by the illumination device may be improved. Alternatively or additionally, light emitted via the light out-coupling side of the semiconductor light-emitting element at the region thereof not covered by the wavelength converting member may be redirected towards said lateral side of the wavelength converting member by the light redirecting and/or absorbing member, resulting in a higher color purity, and also in increased efficiency since a higher proportion of the total light emitted by the semiconductor light-emitting element may be converted and subsequently emitted by the wavelength converting member.

Typically, when said light redirecting and/or absorbing member serves to redirect the unconverted light, the light redirecting and/or absorbing member may be referred to as a light redirecting member and may comprise a reflective and/or scattering domain. For example, the reflective and/or scattering domain may comprise reflective and/or scattering elements dispersed in a carrier material. Scattering of unconverted light improves the mixing of converted and unconverted light leaving the illumination device, thus reducing local differences (e.g. deviating color) in the emission spectrum. Alternatively, the reflective and/or scattering domain may comprise a reflective domain, typically a reflective layer, arranged to redirect light that is out-coupled via the region of the light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting member, towards the lateral side of the wavelength converting member.

Furthermore, the light redirecting and/or absorbing member may comprise a transparent domain. A transparent domain may serve as a light guide directing unconverted light towards the lateral side of the wavelength converting member. Optionally, the transparent domain may be coated with a reflective layer.

In embodiments of the invention, said region of the light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting member may be located adjacent a lateral edge of the semiconductor light-emitting element. Furthermore, the light redirecting and/or absorbing member may fully cover the part of the light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting element. The wavelength converting member may comprise an opening, e.g. a hole, a slit or a cavity, defining said region of the light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting member. Thus, the illumination device according to embodiments of the invention allows many different configurations and arranging methods. For example, a hole in the wavelength converting member through which an electrically conductive member may contact the semiconductor light-emitting element may have a small area and may be provided at any suitable position. Where the region not covered by the wavelength converting member is defined by a slit or a cavity, which may extend from a lateral side of the wavelength converting member, an electrically conductive member may be arranged in the slit or cavity so as to not obstruct the top side of the wavelength converting member.

Said electrically conductive member may be a wire, in particular a bond wire.

In a second aspect, the invention relates to an array of illumination devices as described above. Such an array may be an illumination device comprising:

- a plurality of semiconductor light-emitting elements, such as an array of LEDs, each having a light out-coupling side;
- a wavelength converting member covering a region of said light out-coupling side of each semiconductor light-emitting element and not covering another region of the light out-coupling side of each semiconductor light-emitting element; and/or a plurality of wavelength converting members, each one covering a region of said light out-coupling side of one of said plurality of semiconductor light-emitting elements and not covering another region of the light out-coupling side of said semiconductor light-emitting element;
- a plurality of electrically conductive elements, each semiconductor light-emitting element being contacted, directly or indirectly, by at least one of said electrically conductive members at said region of its light out-coupling side not covered by said at least one wavelength converting member; and
- a light redirecting and/or absorbing member arranged on the light out-coupling side of each semiconductor light-emitting element at the region thereof not covered by the at least one wavelength converting member and in direct or indirect contact with a lateral side of said wavelength converting member.

Thus, a multi-LED based illumination device is provided which has improved color homogeneity and/or color purity as described above.

In a further aspect, the invention relates to a method for producing an illumination device according to said first or second aspect of the invention, comprising steps of:

- arranging a wavelength converting member on a light out-coupling side of a semiconductor light-emitting element such that a region of said light out-coupling side of the semiconductor light-emitting element is not covered by the wavelength converting member;
- contacting said light out-coupling side of the semiconductor light source with an electrically conductive member at the region of said light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting member; and

- applying a light redirecting and/or absorbing member on said region of the light out-coupling side of the semiconductor light-emitting element not covered by the wavelength converting member.

Preferably, the wavelength converting member may be a ceramic plate. Thus, the invention provides a simple method for producing an illumination device which may produce light of improved color homogeneity and/or color purity as described above. Furthermore, the step of arranging the wavelength converting member on the semiconductor light-emitting element may be performed either before or after the step of contacting the semiconductor light-emitting element with an electrically conductive member, thus allowing various device and/or process designs.

It is noted that the invention relates to all possible combinations of features recited in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

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.

Fig. 1a is a perspective view of an illumination device according to embodiments of the invention;

Fig. 1b is a side view of the illumination device of Fig. 1a;

Fig. 2a is a cross-sectional side view of an illumination device according to embodiments of the invention;

Fig. 2b is a cross-sectional side view of an illumination device according to embodiments of the invention;

Fig 3a-d present top views of illumination devices according to embodiments of the invention;

Fig. 4 is a perspective view of an illumination device according to further embodiments of the invention.

DETAILED DESCRIPTION

As illustrated in the figures, the sizes of layers and regions are exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of embodiments of the present invention. Like reference numerals refer to like elements throughout.

Fig. 1 illustrates an illumination device 1 according to embodiments of the invention. The illumination device 1 comprises an LED die 2 arranged on a submount 3. A wavelength converting member 4 having the shape of a plate is provided on the light out-coupling side of the LED 2 to cover a major part thereof. However, a region of the light out-coupling side of the LED 2 is not covered by the wavelength converting member 4. Typically, the top side of the LED relative to the submount 3 may be the light out-coupling side of the LED. Top electrodes in the form of bond wires 5 contacts the region of the out-coupling side of the LED 2 not covered by the wavelength converting member 4, possibly via electric contact pads, and also contacts an electric contact pad (not shown) on the submount 3. Another electric contact (not shown) of the LED 2 may be provided on the side of the LED facing the submount 3 (bottom side of the LED relative to the submount 3). Furthermore, a light redirecting and/or absorbing member 6 in the form of a scattering composition is provided on the region of the LED 2 not covered by the wavelength converting member 4 and encloses part of the bond wire 5.

The LED 2 may be adapted to emit light of any desirable wavelength range; for example the LED may have an emission maximum in the range of from 420 to 470 nm. Thus, a first wavelength range emitted by the LED may be from 400 to 500 nm, e.g. 420 to 470 nm. However, the LED may also emit light of wavelengths in the UV range, such as from 280 nm to 400 nm. For example, the LED 2 may be a InGaN based LED, but other LEDs are also possible to use in embodiments of the present invention.

The wavelength converting member 4 is provided on the light out-coupling side of the LED 2 such that light emitted from the LED 2 via the light out-coupling side thereof may be received by the wavelength converting member 4 for subsequent wavelength conversion. The wavelength converting member 4 typically comprises a wavelength converting material, such as a phosphor. The type of wavelength converting material chosen may depend on the emission wavelengths of the LED 2 and also on the desired spectral output of the illumination device.

The wavelength converting member 4 may be a ceramic layer, for example a ceramic slab as described in WO 2005/119797. A self supporting ceramic layer may be formed by heating a particulate phosphor material at high pressure until the surface of the particles begin to soften melt; the partially melted particles then stick together to form a rigid agglomerate of phosphor, as is described in WO 2005/119797 on page 4 lines 25-27. Advantageously, since there are small optical discontinuities between the individual phosphor particles, such a ceramic layer is optically almost homogeneous and has the same refractive index as the phosphor material forming said layer.

When the wavelength converting member is a ceramic layer no binder material for the phosphor particles is required, other than the phosphor itself. Hence, such a ceramic layer may be transparent or translucent.

Examples of suitable phosphor materials that may be used in the present invention include those mentioned in WO 2005/119797 on page 4, lines 12-24, including inter alia green-yellow (wavelength range of 500-600 nm) emitting aluminum garnet phosphors of the general formula $(Lu_{1-x-y-a-b}Y_xGd_y)_3(Al_{1-z}Ga_z)_5O_{12}$, where $0 < x < 1$, $0 < y < 1$, $0 < z \leq 0.1$, $0 < a \leq 0.2$ and $0 < b \leq 0.1$, for example $Lu_3Al_5O_{12}:Ce^{3+}$ and $Y_3Al_5O_{12}:Ce^{3+}$. In general, light of the second wavelength range emitted by the wavelength converting member may be from 450 nm to 750 nm.

The wavelength converting member may be arranged on the light out-coupling side of the LED. The wavelength converting member may be attached to the LED by means of wafer bonding, sintering or gluing using organic adhesives, inorganic adhesives, or sol-gel glasses. For example, adhesives and sol-gel glasses such as those mentioned in WO 2005/119797, page 5, line 7- page 6, line 7 may be used.

Fig 1b, which is a side view of the illumination device of Fig. 1a, shows more clearly the light redirecting member 6, which is in the form of a scattering composition provided on the LED 2 around the bond wire 5 and in contact with a lateral side of the wavelength converting member 4. The scattering composition serves to scatter unconverted light that is out-coupled via the region of the LED 2 not covered by the wavelength converting member 4. Thus, unconverted light may be at least partly redirected towards the lateral side of the wavelength converting member coupled into it for subsequent wavelength conversion, and/or scattered and mixed with wavelength converted light emitted by the wavelength converting member 4. As a result of the scattering, local variations in the spectral properties of the total outgoing light are reduced or avoided, and a more homogeneous light output is obtained. Advantageously, the scattering composition covers a major part of the region not covered by the wavelength converting member 4, and preferably fully covers said region, except for the area already occupied by the bond wire connection.

As used herein with respect to the light redirecting and/or absorbing member, “scattering” refers to scattering of light of the first wavelength range emitted by the LED, i.e. unconverted light.

The scattering composition may comprise a carrier which may comprise sol-gel monomers, e.g. an alkyl alkoxy silane, such as methyl trimethoxy silane, or a silicone resin. The sol-gel monomers may be (partially) hydrolyzed and polymerized in a liquid composition, which may contain water and/or alcohols. Hence, this type of fluid is typically hydrophilic (polar). The carrier composition may contain various amount of solvent(s) e.g. in order to tune the viscosity of the fluid. In uncured form, a silicone resin typically is a fluid and may be used as such, or optionally a solvent may be added to the silicone resin to tune its viscosity. Commercially available silicone resins exist in many chemical compositions and material properties.

Furthermore, scattering and/or reflecting elements may be dispersed in the carrier composition. For example, scattering particles, such as metal oxide (e.g. TiO_2, ZrO_2 and/or Al_2O_3) particles, reflective, diffusive or luminescent metal flakes, and/or absorbing dyes or pigments may be dispersed in the composition. Alternatively, the scattering composition according to the invention may be a composition comprising pores which provide a scattering function.

The scattering composition according to the invention may be amorphous.

In embodiments of the invention the scattering composition may be highly reflective, so as to reflect unconverted light incident from the LED 2 with an efficiency of e.g. 90-95 %.

In preferred embodiments, the scattering composition may comprise scattering metal oxide particles dispersed in a carrier composition, such as silicone. The use of silicone as a carrier may be particularly advantageous since silicone has a relatively high thermal stability, it is relatively easy to process and it provides mechanical protection as well as protection against humidity and moisture.

In embodiments of the invention, the light redirecting and/or absorbing member may comprise a light absorbing composition instead of, or in addition to, a scattering composition as described above. Alternatively, the light redirecting member may comprise a composition that is partly scattering and partly absorbing.

By absorbing at least part of the unconverted light out-coupled via the region of the LED not covered by the wavelength converting member, the color purity of the output light may be increased.

As used herein with respect to the light redirecting member, “absorbing” refers to absorbing of light of the first wavelength range emitted by the LED, i.e. unconverted light.

For an absorbing composition, various types of material may be used:

- polymeric materials or other plastic materials, including silicone and epoxy resins, optionally comprising filler material;
- ceramic materials, including ceramic composites, such as Al_2O_3, AlN, titanium oxides, SiN, SiO, SiO_xN_y, or other oxides or nitrides;
- metals, for example silver, aluminum, copper, gold, tin, tungsten, nickel, and iron;
- carbon based materials, e.g. graphite.

The above materials may be applied in the form of a layer and/or in the form of particles. In particular, the metal materials may be applied in the form of a metal layer or in the form of particles in suspension. The above ceramic materials may be at least partly absorbing depending on the geometry of said layer or particles.

The use of an absorbing composition may reduce the leakage of unconverted light such that substantially no unconverted light is out-coupled from the illumination device. For example, the ratio of the intensity of unconverted light leaving the illumination device to the intensity of converted light leaving the illumination device may be less than 1:50, preferably less than 1:100, more preferably less than 1:500 and most preferably less than 1:1000. These ratios refer to the light emitted by the illumination device as a whole, which includes light of the second wavelength range emitted by the wavelength converting member and light of the first wavelength range which has escaped both absorption and conversion and thus is out-coupled from the illumination device. The light intensity may be measured e.g. in lumen output or as light flux in a certain angle.

Fig 2a illustrates an illumination device according to another embodiment of the invention from a cross-sectional side view. The device 1 comprises a semiconductor light-emitting element 2 (typically an LED) arranged on a submount 3, a wavelength converting member 4 and a bond wire 5, all of which may be as described above with reference to the embodiment shown in Fig. 1a. The description will therefore now focus on the features distinguishing the embodiment of Fig. 2a from Fig 1a.

A light redirecting member is provided on the region of the LED 2 not covered by the wavelength converting member 4. In this embodiment, the light redirecting member comprises a transparent domain 61 and a reflective and/or scattering domain 62. The transparent domain 61 is arranged on the LED 2 and in direct or indirect contact with a lateral side of the wavelength converting member 4. A small air gap between the transparent domain 61 and the wavelength converting member 4 may be allowed. The transparent domain is typically transparent to light of said first wavelength range emitted by the LED 2 (unconverted light). The transparent domain 61 is covered by the reflective and/or scattering domain 62, which may prevent at least part of the unconverted light from escaping the light redirecting member and redirects it towards the lateral side of the wavelength converting member 4 via the transparent domain 61. Thus, the unconverted light out-coupled via the region of the LED 2 not covered by the wavelength converting member 4 may be coupled into the wavelength converting member for subsequent wavelength conversion. Also, advantageously, only little or no light is redirected back towards the LED 2.

Similarly to the use of an absorbing member, the use of a redirecting member may reduce the leakage of unconverted light such that substantially no unconverted light is out-coupled from the illumination device. Moreover, a light redirecting member may increase the proportion of light emitted by the LED that is converted by the wavelength converting member, thus also increasing the efficiency of the illumination device and further reducing the ratio of unconverted to converted light emitted by the illumination device. Still, however, the ratio of the intensity of unconverted light leaving the illumination device to the intensity of converted light leaving the illumination device may be less than 1:50, preferably less than 1:100, more preferably less than 1:500 and most preferably less than 1:1000. These ratios refer to the light emitted by the illumination device as a whole, which includes light of the second wavelength range emitted by the wavelength converting member and light of the first wavelength range which has escaped both absorption and conversion and thus is out-coupled from the illumination device 1.

The transparent domain 61 may consist of e.g. a transparent resin or a glass, plastic or ceramic body, or it may be an air pocket or comprise an inert gas. Typically, a glass, plastic or ceramic body may be glue bonded or fused to the wavelength converting member 4. However, a small air gap may be allowed between said transparent body 61 and the wavelength converting member 4. In the embodiment illustrated in Fig. 2a, the transparent domain 61 has a curved profile which can be achieved by molding or by dispensing a fluid and allowing capillary forces to act. It is contemplated that other shapes are also possible for the transparent domain, such as rectangular or triangular. Alternatively, the transparent domain may be formed by the bond layer used for bonding the ceramic wavelength converting member 4 to the LED 2. In such embodiments, the bond material may extend upwards along the side of the wavelength converting member 4.

The transparent domain 61 may serve as a light guide, having a geometry and a refractive index causing total internal reflection of at least part of the unconverted light at at least one surface of the transparent domain 61, such that it is not necessary to use a reflective and/or scattering domain 62 outside the transparent domain 61 for redirecting the unconverted light towards the lateral side of the wavelength converting member 4. Thus, depending on the properties of the transparent domain 61, the reflective and/or scattering domain 62 may be optional.

The reflective and/or scattering domain 62 may be a scattering composition as described above, for example a binder material comprising TiO_2, Al_2O_3 or ZrO_2 pigment. The binder material may be e.g. a silicone resin or a sol gel derived binder, such as methyl silicate. Thus, the reflective and/or scattering domain 62 may be a diffuse scattering reflector.

Alternatively, the reflective and/or scattering domain 62 may comprise metal flakes, e.g. aluminum flakes, dispersed in a binder. In such embodiments, the reflective and/or scattering domain 62 may provide at least partial specular reflection.

In embodiments of the invention, the reflective and/or scattering domain 62 may be a metal reflector, e.g. comprising metal deposited as a layer on a transparent body. The metal may be deposited onto the transparent domain 61, in particular where the transparent domain is a resin body, a glass body or a ceramic body as described above. Typically, in such embodiments, the metal layer is deposited on the transparent body before attachment to the semiconductor light-emitting element 2. Alternatively, the metal reflector may comprise a metal self-supporting metal film which is formed into a desired shaped, e.g. curved. The metal film may then be bonded to the transparent domain 61, or it may be bonded to the semiconductor light-emitting element 2 before the application of the transparent domain 61 so as to define a space to be filled with the transparent domain 61, in particular a transparent resin. A metal layer may be adhered to the semiconductor light-emitting element and optionally the wavelength converting member 4 by an adhesive which may also serve as the transparent domain 61.

Furthermore, in embodiments of the invention, the reflective and/or scattering domain 62 may be a hybrid reflector comprising a scattering layer covered by a metal layer.

Fig. 2b illustrates another embodiment of the invention comprising a transparent domain 61 and a reflective and/or scattering domain 62 as described above. In this embodiment, the reflective and/or scattering domain 62 may be applied not only on the light out-coupling side of the LED 2, but also to cover a lateral side of the LED 2 adjacent the region thereof not covered by the wavelength converting member 4, and also to cover part of the submount 3. Thus, light that is out-coupled via the lateral side of the LED 2 instead of the main light out-coupling side on which the wavelength converting member 4 is arranged, may be guided to the wavelength converting member 4 via the reflective and/or scattering domain

62 and the transparent domain 61, or scattered by the reflective and/or scattering domain 62. Furthermore, as is also illustrated in Fig. 2b, a reflective and/or scattering domain may also be provided on the submount to cover a lateral side of the LED 2 that is not adjacent a region thereof not covered by the wavelength converting member 4.

Fig 3a-d schematically illustrate top views of exemplary embodiments of the invention showing some alternative locations of the region of the LED 2 not covered by the wavelength converting member 4. In order to simplify the illustration, the redirecting and/or absorbing member is not shown in these figures, but it is understood that the redirecting and/or absorbing member may be applied in these embodiments as well.

As seen in Fig. 3a, a region 7 of the LED 2 not covered by the wavelength converting member 4 may be defined by a rectangular opening 7 in the wavelength converting member 4 in the form of a slit from the side. Alternatively, as seen in Fig 3b, the wavelength converting member 4 may also have a cut corner, thus leaving a corner region 7 of the LED 2 uncovered. It is contemplated that the corner of the wavelength converting member 4 may be cut in any suitable shape, e.g. to define a quadratic, rectangular or part-circular region.

To increase robustness and current density it may be desirable to apply two bond wires, as illustrated in the embodiments of Figs. 1a, 3c and 3d. However, it is also contemplated that a wavelength converting member may be applied over two or more LEDs, preferably arranged close together, so that part of a light out-coupling side of each individual LED is exposed by the wavelength converting member, for example by means of cut corners as illustrated in Figs. 3c or 3d.

Fig. 4 illustrates a further embodiment of the invention, in which the region of the LED 2 not covered by the wavelength converting member 4 is defined by an opening 7 in the form of a circular hole located centrally in the wavelength converting member 4. The circular hole may be obtained e.g. by drilling. However, the opening may be located at any distance from a lateral side of the wavelength converting member 4. The opening 7 allows an electrically conductive member to be arranged therein. As illustrated in Fig. 4, a bond wire 5 may extend through the opening 7 so as to contact the light out-coupling side of the LED 2, directly or indirectly, possibly via a contact pad (not shown) provided on the light out-coupling side of the LED 2. The bond wire 5 is partly surrounded by a light redirecting member 6 in the form of a scattering composition applied in the opening.

The opening 7 may have any suitable shape, such as circular, triangular, quadratic, rectangular, trapezoid or other polygonal shapes, or any irregular shape. The shape and/or the position of the opening may be adapted to fit with the electrically conductive member, e.g. a bond wire, to be arranged therein, and/or in order to facilitate mounting of the wavelength converting member and/or the electrically conductive member.

The opening 7 may be located at any suitable position relative to the LED 2. For example, the opening 5 may be located centrally in the wavelength converting member, which may also be centrally relative to the LED.

In another aspect, the invention relates to a wavelength converting member for use in a semiconductor light source based illumination device, such as an LED based illumination device, which wavelength converting member comprises an opening allowing an electrically conductive member to be arranged therein, the opening further comprising a light redirecting and/or absorbing member. Advantageously the light redirecting member may be a scattering and/or reflective composition, e.g. scattering elements dispersed in a carrier such as silicone. For example, the opening may be a hole or a slit as described above with reference to Figs 3 and 4.

In a further aspect, the invention relates to a method for producing an illumination device as described above. The method comprises providing a semiconductor light-emitting element having a light out-coupling side; arranging a wavelength converting member on part of the semiconductor light-emitting element such that a region of the semiconductor light-emitting element is not covered by the wavelength converting member; contacting a light out-coupling side of the semiconductor light-emitting element with at least one electrically conductive member; and applying a light redirecting and/or absorbing member on the region of the semiconductor light-emitting element not covered by the wavelength converting element.

Typically, a vertical LED is arranged on a submount 3 and contacted via a back electrode on the submount by conventional means. A wavelength converting member, typically a ceramic plate, may then be applied e.g. by gluing onto the LED so as to partly cover the LED, and subsequently the at least one top electrode is bonded to the region of the LED not covered by the wavelength converting member. Alternatively, the electrode may be attached to the LED before the wavelength converting member is applied. Attaching the wavelength converting member before the top electrode may be preferred since it allows gluing of the wavelength converting member with good optical and thermal contact, and thus provides a robust and reliable manufacturing step. However, in some cases, connecting the top electrode(s) before attaching the wavelength converting member may be preferred due to better electrode contact.

The light redirecting and/or absorbing member is applied after connecting the at least one top electrode, and may cover at least a part, and preferably a major part, of the region of the LED not covered by the wavelength converting element.

In embodiments where the light redirecting and/or absorbing member is a scattering composition, it may be applied as a fluid or fluidic suspension or solution by conventional means, e.g. using a syringe, ink jet printing or the like. Once applied on the region of the LED not covered by the wavelength converting member, a liquid scattering composition may be solidified and optionally formed into a desirable shape. Solidification may occur by any solidifying action, for example by air drying to remove solvents, and/or curing the composition using standard curing techniques. As an example, for solidification of a sol-gel monomer, the composition may be dried for about 10 minutes to evaporate most solvents. The composition may then be further dried at 90 °C for about 20 min and subsequently the sol gel may be formed into a brittle methyl silicate network by curing at 200 °C for 1 h. For a silicone based composition, curing may be performed using UV irradiation, elevated temperature or air exposure, to form a soft solid composition.

In embodiments where the light redirecting and/or absorbing member comprises a transparent domain and a reflective and/or scattering domain, the transparent domain may be applied as a fluid and solidified as described above, or applied as a solid body and glued to the LED and optionally to the wavelength converting member. A small air gap may be allowed between the transparent domain body and the wavelength converting member 4. The reflective and/or scattering domain may be deposited onto the transparent domain before or after application thereof as described above with reference to the embodiment illustrated in Fig. 2a. Alternatively, in embodiments where the reflective and/or scattering domain comprises a self-supporting film, the reflective and/or scattering domain may be bonded to the LED before application of a transparent domain. In such embodiments, an air pocket enclosed by the LED, the wavelength converting member and the reflective and/or scattering domain may form the transparent domain.

Furthermore, according to another aspect of the invention, the wavelength converting member or the illumination device described above may be applied in an illumination device comprising an array of semiconductor light-emitting elements, e.g. LEDs. In such embodiments comprising a plurality of LEDs, a single wavelength converting member may cover a region of the light out-coupling side of each LED and leave another region of the light out-coupling side of each LED uncovered (for example by comprising a plurality of openings located at suitable positions, corresponding to the individual LEDs).

Alternatively, a plurality of wavelength converting members may be used, each covering a region of at least one LED. Embodiments according to this aspect of the invention may further comprise a plurality of light redirecting and/or absorbing members, each redirecting and/or absorbing member being arranged on the light out-coupling side of an LED at the region thereof not covered by the wavelength converting member. However, it is also contemplated that a single light redirecting and/or absorbing member may be used, e.g. in the form of a light guide covering a region of each LED.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims.

CLAIMS:

1. Illumination device (1) comprising:

- a semiconductor light-emitting element (2) having a light out-coupling side;
- a wavelength converting member (4) arranged on a region of said light out-coupling side of the semiconductor light-emitting element (2) such that another region of said light out-coupling side of the semiconductor light-emitting element (2) is not covered by said wavelength converting member (4);
- an electrically conductive member (5) contacting, directly or indirectly, said light out-coupling side of the semiconductor light-emitting element (2) at said region of the light out-coupling side of the semiconductor light-emitting element (2) not covered by the wavelength converting member (4), and
- a light redirecting and/or absorbing member (6) arranged on said light out-coupling side of the semiconductor light-emitting element (2) at the region thereof not covered by the wavelength converting member (4) and in direct or indirect contact with a lateral side of said wavelength converting member (4), such that, in operation, light emitted via the light out-coupling side of the semiconductor light-emitting element (2) at the region thereof not covered by the wavelength converting member is absorbed or redirected by the light redirecting and/or absorbing member (6).

2. Illumination device according claim 1, wherein the wavelength converting member (4) comprises a ceramic body.

3. Illumination device according to claim 1 or 2, wherein, in operation, said semiconductor light-emitting element (2) emits light of a first wavelength range and said wavelength converting member (4) emits light of a second wavelength range and wherein the ratio of the intensity of light of said first wavelength range emitted by the illumination device to the intensity of light of said second wavelength range emitted by the illumination device is less than 1:50, preferably less than 1:100, more preferably 1:500 and most preferably 1:1000.

4. Illumination device according to claim 3, wherein said light redirecting and/or absorbing member (6) absorbs light of said first wavelength range emitted via the region of the light out-coupling side of the semi

5. Illumination device according to any one of the claims 1 to 3, wherein, in operation, light emitted via the light out-coupling side of the semiconductor light-emitting element (2) at the region thereof not covered by the wavelength converting member (4) is redirected towards said lateral side of the wavelength converting member (4) by the light redirecting and/or absorbing member (6).

6. Illumination device according to claim 5, wherein said redirecting and/or absorbing member (6) comprises a reflective and/or scattering domain.

7. Illumination device according to claim 6, wherein said reflective and/or scattering domain comprises reflective and/or scattering elements dispersed in a carrier material.

8. Illumination device according to claim 6, wherein said reflective and/or scattering domain comprises a reflective layer.

9. Illumination device according to any one of the claims 5 to 8, wherein said light redirecting and/or absorbing member (6) comprises a transparent domain.

10. Illumination device according to any one of the preceding claims, wherein said light redirecting and/or absorbing member (6) is arranged at the region of the light out-coupling side of the semiconductor wavelength converting element (2) that is contacted by said electrically conductive member (5).

11. Illumination device according to any one of the preceding claims, wherein said region of the light out-coupling side of the semiconductor light-emitting element (2) not covered by the wavelength converting member (4) is located adjacent a lateral edge of the semiconductor light-emitting element (2).

12. Illumination device according to any one of the claims 2 to 9, wherein the wavelength converting member (4) comprises an opening defining said region of the light out-coupling side of the semiconductor light-emitting element (2) not covered by the wavelength converting member (4).

13. Illumination device according to any one of the preceding claims, wherein said electrically conductive member (5) is a bond wire.

14. Illumination device according to any one of the preceding claims, comprising:

- a plurality of semiconductor light-emitting elements each having a light out-coupling side;
- a wavelength converting member covering a region of said light out-coupling side of each semiconductor light-emitting element and not covering another region of the light out-coupling side of each semiconductor light-emitting element; and/or a plurality of wavelength converting members, each one covering a region of said light out-coupling side of one of said plurality of semiconductor light-emitting elements and not covering another region of the light out-coupling side of said semiconductor light-emitting element,
- a plurality of electrically conductive elements, each semiconductor light-emitting element being contacted, directly or indirectly, by at least one of said electrically conductive members at said region of the light out-coupling side not covered by said at least one wavelength converting member, and
- a light redirecting and/or absorbing member arranged on the light out-coupling side of each semiconductor light-emitting element at the region thereof not covered by the at least one wavelength converting member and in direct or indirect contact with a lateral side of said wavelength converting member.

15. Method for producing an illumination device according to any one of the claims 1 to 14, comprising steps of:

- arranging a wavelength converting member (4) on a light out-coupling side of a semiconductor light-emitting element (2) such that a region of said light out-coupling side of the semiconductor light-emitting element (2) is not covered by the wavelength converting member (4);
- contacting said light out-coupling side of the semiconductor light source (2) with an electrically conductive member (5) at the region of said light out-coupling side of the

semiconductor light-emitting element (2) not covered by the wavelength converting member (4); and

- applying a light redirecting and/or absorbing member on said region of the light out-coupling side of the semiconductor light-emitting element (2) not covered by the wavelength converting member (4).

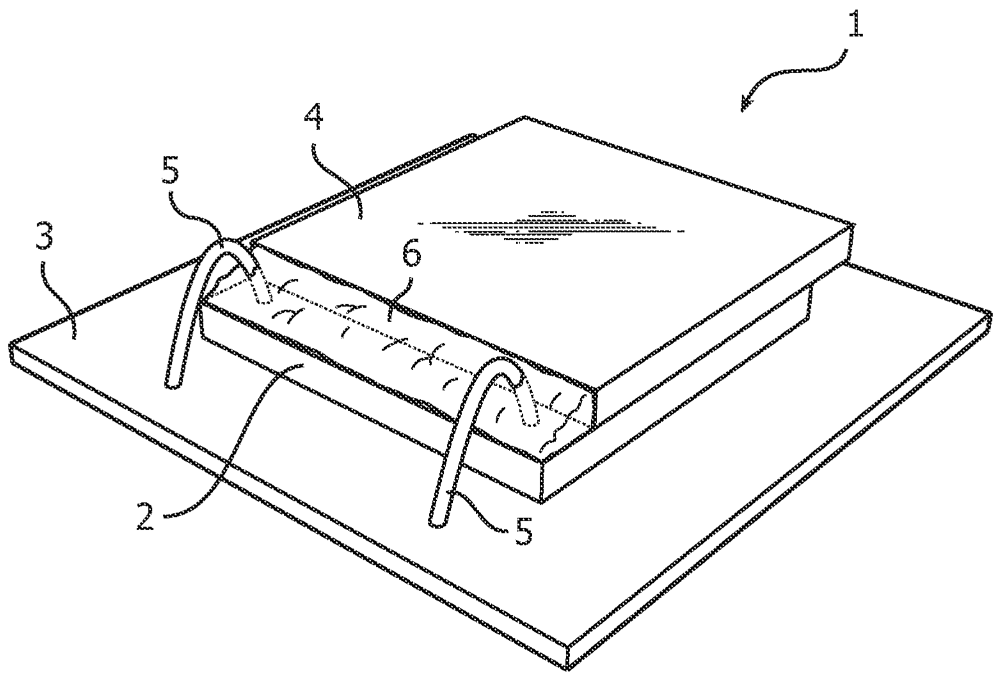

FIG. 1a

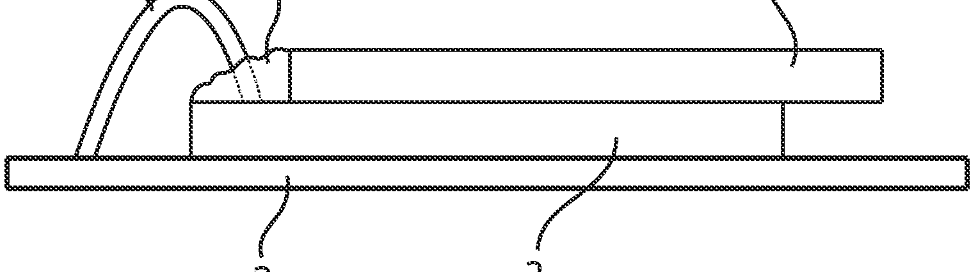

FIG. 1b

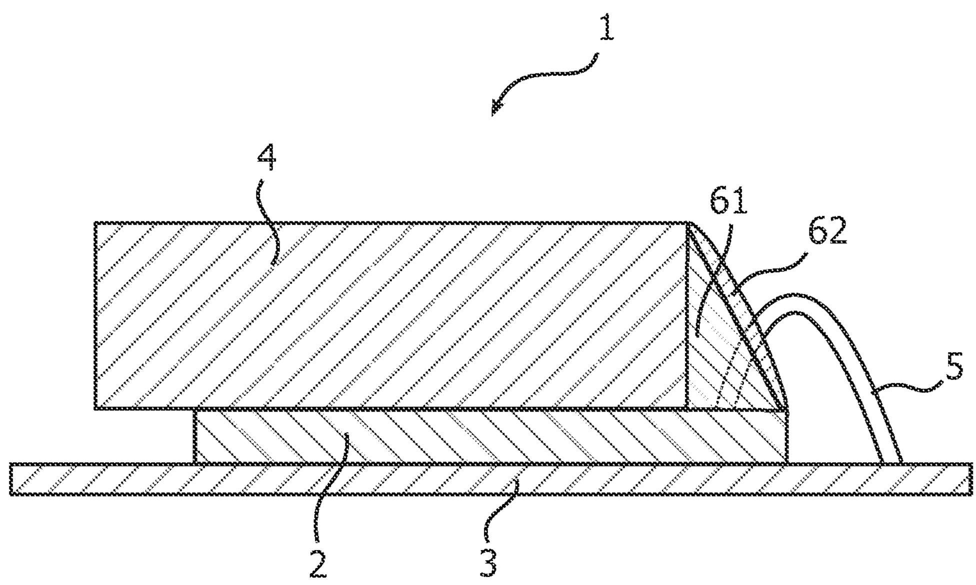

FIG. 2a

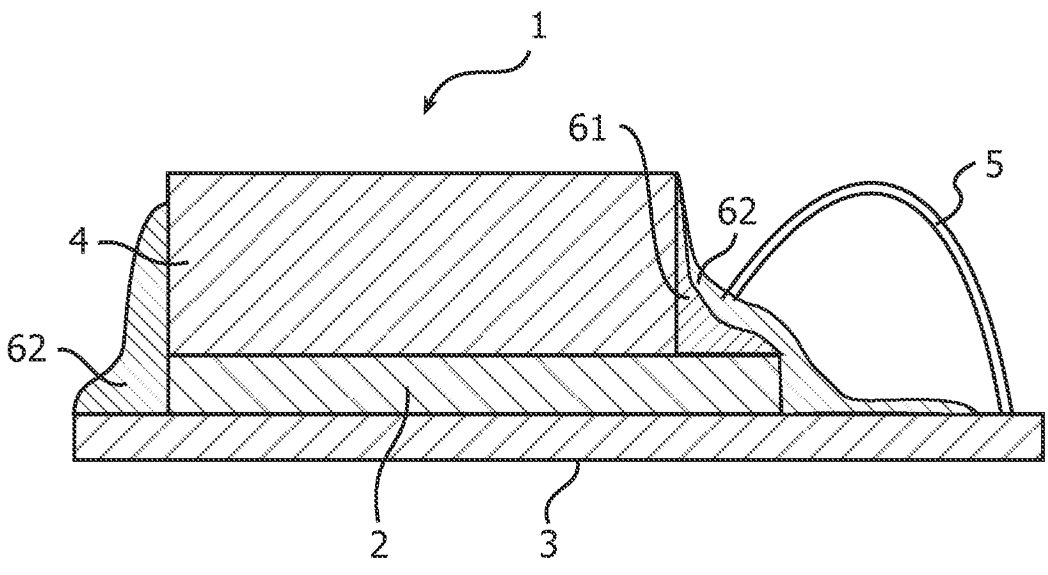

FIG. 2b

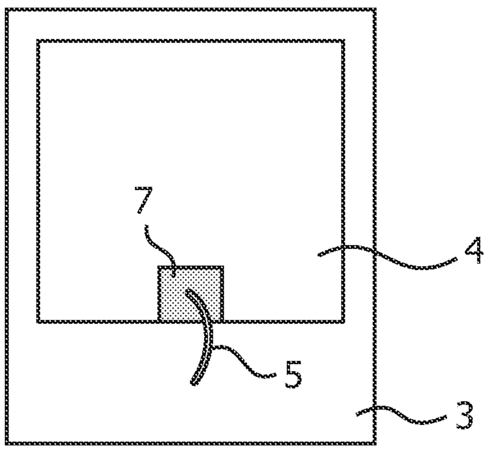

FIG. 3a

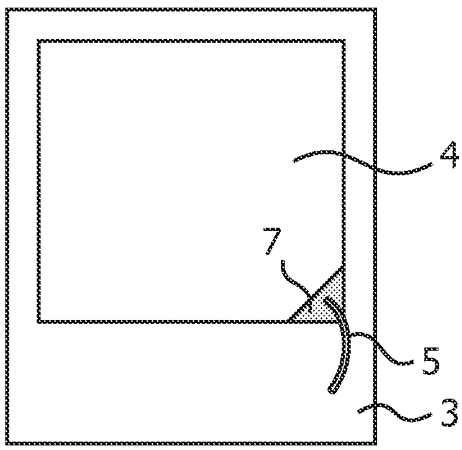

FIG. 3b

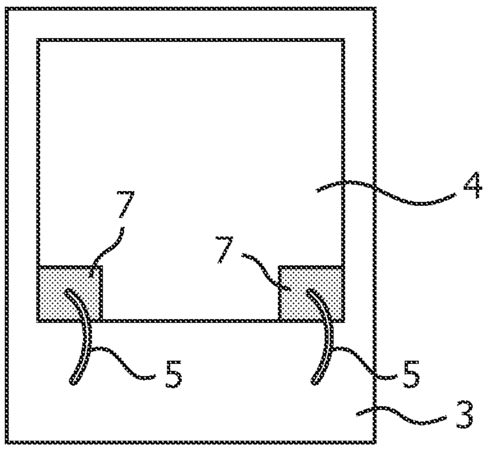

FIG. 3c

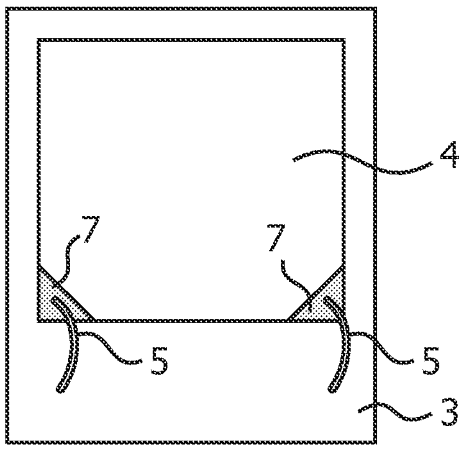

FIG. 3d

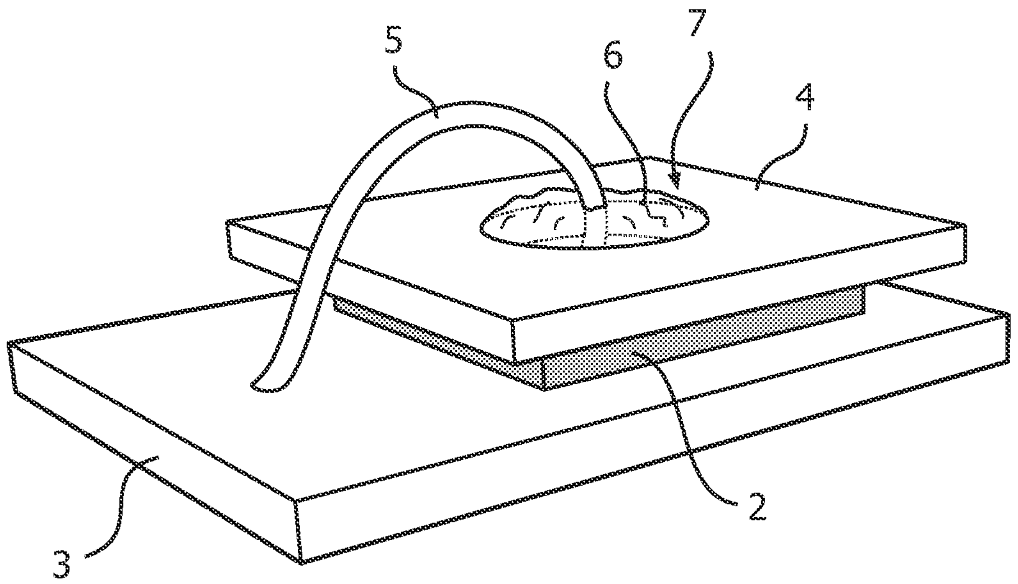

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2010/052507

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L33/44
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L

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

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Y	paragraph [0040]; figure 3 paragraph [0053] - paragraph [0055]	14
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search

24 August 2010

Date of mailing of the international search report

06/09/2010

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