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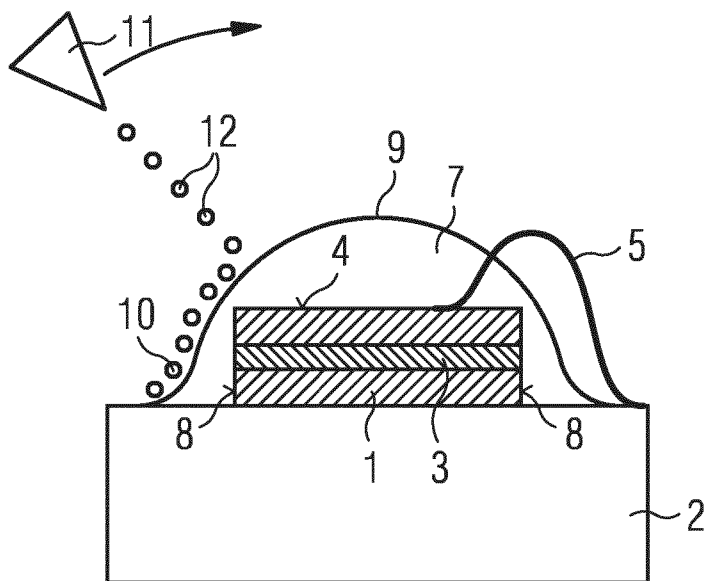
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- (54) Title: OPTOELECTRONIC DEVICE AND METHOD FOR THE PRODUCTION THEREOF

FIG 4



- (57) Abstract: A method for producing an optoelectronic device comprising the following steps is provided: -providing a semiconductor chip(1), which emits electromagnetic radiation of a first wavelength range from a radiation exit surface(4) during operation, -coating at least the radiation exit surface (4) with a light-transmitting resin layer(7), -coating a surface (9) of the light-transmitting resin layer (7) with a powder layer(10)comprising phosphor particles (12), wherein the phosphor particles(12)are configured to convert the light of the first wavelength range in electromagnetic radiation of a second wavelength range, and -curing the light-transmitting resin layer(7). Furthermore, an optoelectronic device is provided.

Description

Optoelectronic device and method for the production thereof

- 5 An optoelectronic device and a method for producing an optoelectronic device are provided.

It is an object of the present invention to provide a method for the production of an optoelectronic device with a
10 homogenized radiation characteristic. Furthermore, a simplified method for the production of such an optoelectronic device should be provided.

These objects are achieved by a method with the steps of
15 claim 1 and an optoelectronic device with the features of claim 12. Advantageous embodiments and developments are subject-matter of the dependent claims.

A method for producing an optoelectronic device has the step
20 of providing a semiconductor chip, which emits electromagnetic radiation of a first wavelength range from a radiation exit surface during operation. The electromagnetic radiation of the first wavelength range is preferably blue light.

25

The radiation exit surface is coated with a light-transmitting resin layer. For example, the light-transmitting resin layer comprises at least one of the following materials or is formed of one of the following materials: silicone,
30 epoxy resin. It is also possible that the light-transmitting resin layer comprises a mixture of silicone and epoxy resin or is formed of a mixture of silicone and epoxy resin.

A surface of the light-transmitting resin layer is coated with a powder layer. The powder layer comprises phosphor particles, which are configured to convert electromagnetic radiation of the first wavelength range in electromagnetic radiation of a second wavelength range. The second wavelength range is different from the first wavelength range. The powder layer can also be formed of the phosphor particles.

Preferably, the second wavelength range is green and/or yellow light.

Particularly preferably, the light-transmitting resin layer transmits at least electromagnetic radiation of the first and the second wavelength range. For example, the light-transmitting resin layer transmits visible light. Preferably, the light-transmitting resin layer is transparent for radiation of the first wavelength range and/or for radiation of the second wavelength range and/or for visible light. For example, the light-transmitting resin layer has a transmission coefficient of at least 0.85, preferably of at least 0.9 and particularly preferably of at least 0.95 for radiation of the first and the second wavelength range and/or for visible light.

According to an embodiment of the method, the light-transmitting resin layer is cured after the deposition of the powder layer. During curing, the material of the light-transmitting resin layer is cross-linked. Curing of the light-transmitting resin layer can be done by radiation with ultraviolet radiation, heat or a crosslinking agent.

The radiation exit surface can be coated with the light-transmitting resin layer by jetting.

The surface of the light-transmitting resin layer is preferably coated with the phosphor particles by electrostatic deposition, such as electrostatic spraying with a powder gun. The powder gun imparts a positive electric charge to the phosphor particles of the powder. Then the powder is sprayed towards the target surface, which is grounded. During spraying, the particles of the powder are accelerated towards the target surface by the electrostatic charge. At present, the powder of phosphor particles is sprayed towards the grounded surface of the light-transmitting resin layer such that a powder layer is formed on the surface of the light-transmitting resin layer. The spraying of the powder can be performed in a mechanically or by compressed air. For example, the powder gun is moved over the surface of the light-transmitting resin layer in a lateral direction during the spraying process.

By electrostatic spraying, a free flowing dry powder is applied in general. In particular, the electrostatic spraying does not require a liquid, such as a binder or a solvent, for deposition.

Preferably, the resin layer acts as adhesive for the powder layer. The resin layer has adhesive properties, which fix the powder layer on the resin layer at least in a cured state.

Preferably, the powder layer covers the light-transmitting resin layer completely.

According to a further embodiment, the light-transmitting resin layer is in direct contact with the radiation exit surface of the semiconductor chip. Also, the powder layer is

preferably in direct contact with the light-transmitting resin layer.

According to a further embodiment, the powder layer comprises
5 a further kind of phosphor particles. The further phosphor particles preferably convert the electromagnetic radiation of the first wavelength range in electromagnetic radiation of a third wavelength range. The third wavelength range is
different from the first wavelength range and the second
10 wavelength range. Since the phosphor particles are processed separately from the resin, disadvantageous properties of the finished device due to particle separation caused by different particle properties can be at least reduced by the present method.

15 Particularly preferably, the light-transmitting resin layer transmits also electromagnetic radiation of the third wavelength range, if a further kind of phosphor particles is used. Preferably, the light-transmitting resin layer is
20 transparent for radiation of the third wavelength range. For example, the light-transmitting resin layer has a transmission coefficient of at least 0.85, preferably of at least 0.9 and particularly preferably of at least 0.95 for radiation of third wavelength range.

25 Preferably, the first wavelength range is blue light, the second wavelength range is yellow and/or green light and the third wavelength range is orange and/or red light. With these wavelength ranges an optoelectronic device that emits white
30 light can be produced.

The phosphor particles can comprise one of the following materials or can be formed from one of the following

materials: granates doped with rare earths, sulfides doped with rare earths, thiogallates doped with rare earths, aluminates doped with rare earths, silicates doped with rare earths, orthosilicates doped with rare earths, nitrides doped with rare earths, oxinitrides doped with rare earths, chlorosilicates doped with rare earths, silicon nitrides doped with rare earths, sialones doped with rare earths.

For coating the radiation exit surface of the semiconductor chip with the light-transmitting resin layer a resin mixture can be provided. The resin mixture can be homogenized by centrifugation before applying to the radiation exit surface.

For coating the surface the light-transmitting resin layer with the powder layer, a mixture of phosphor particles can be provided. The phosphor mixture can be also homogenized by centrifugation before applying to the surface of the light-transmitting resin layer.

Particularly preferably, the light-transmitting resin layer is free of wavelength converting properties.

The term „wavelength converting“ means at present that incident electromagnetic radiation of a certain wavelength range is converted in electromagnetic radiation of another wavelength range, which comprises preferably longer wavelengths. In general, a wavelength converting element absorbs incident electromagnetic radiation of a first wavelength range, converts the absorbed radiation at least partially in electromagnetic radiation of a second wavelength range by a molecular and/or atomic mechanism and reemits the converted radiation. In particular, scattering or absorption

alone is not meant with the term "wavelength converting" at present.

According to the present method, the powder layer has
5 wavelength converting properties. Particularly preferably,
the phosphor particles of the powder layer impart the
wavelength converting properties to the powder layer.

According to the present method, a liquid component of a
10 wavelength converting layer, such as the resin, and a powder
component of the wavelength converting layer, such as the
phosphor particles, are separately processed from each other
and deposited in separate layers. Compared to the production
of a conventional wavelength converting layer, wherein a
15 mixture of the liquid component and the powder component is
processed for example by spraying, the present method has the
advantage that separation and sedimentation of the phosphor
particles during the deposition step of the mixture is
prohibited. This leads to a more homogenous radiation
20 characteristic of the finished semiconductor device. Also,
the separation of powder and resin from each other simplifies
handling and preparation and reduces material waste.

Furthermore, the use of harmful solvents during the
25 deposition of the wavelength converting layer as it is
required by spray-coating is not necessary according to the
present method with advantage. This leads to reduced
production costs, since arrangements for protection against
harmful solvent vapor are not necessary.

30

For coating with the light transmitting resin layer, the
semiconductor chip can be provided on a carrier. In this case

also a surface of the carrier can be coated with the light-transmitting resin layer.

It is also possible that a plurality of semiconductor chips
5 is provided on a common carrier. In this case, the method described above can be performed as a batch process. During the batch process, each semiconductor chip is coated with the light-transmitting resin layer by jetting in sequential manner. Then, the surface of each resin layer is coated with
10 the powder layer, preferably also in a sequential manner. Afterwards, the semiconductor devices are singularized, for example by sawing. Due to the sequential processing of the devices, the use of a mask is not necessary as it is required for example by a spray coating process. This reduces the
15 waste of phosphor particles and, as a consequence, the costs. Also, the development of customized masks for different package geometries is not necessary and simplifies production.

20 According to a further embodiment, the semiconductor chip with the light-emitting resin layer and the powder layer is molded with a further resin. Preferably, the further resin embeds the light-transmitting resin layer and the powder layer such that the light-transmitting resin layer and the
25 powder layer are covered completely by the further resin. The further resin protects advantageously the powder layer. The further layer can comprise silicone and/or epoxy or can be formed of silicone and/or epoxy.

30 The optoelectronic semiconductor device which is manufactured for example with the present method comprises preferably a semiconductor chip with an active layer generating electromagnetic radiation of a first wavelength range during

operation of the chip. This electromagnetic radiation is emitted from a radiation exit surface for the semiconductor chip. The semiconductor chip preferably emits radiation of a first wavelength range, which is part of the ultraviolet to green spectral range. Particularly preferably, the semiconductor chip emits blue light.

On the radiation exit surface of the semiconductor chip, a light transmitting resin layer is arranged. Particularly preferably, the light-transmitting resin layer is arranged in the radiation exit surface in direct contact. On the light-transmitting resin layer a powder layer is arranged, preferably also in direct contact with the light-transmitting resin layer. The powder layer comprises phosphor particles, which convert electromagnetic radiation of the first wavelength range in electromagnetic radiation of a second wavelength range.

Particularly preferably, the powder layer converts a part of the electromagnetic radiation of the first wavelength range generated by the active layer in radiation of the second and the third wavelength range, if applicable, and transmits a further part of the electromagnetic radiation of the first wavelength range. In such a way, the optoelectronic semiconductor device emits mixed radiation with electromagnetic radiation of the first wavelength range, electromagnetic radiation of the second wavelength range and electromagnetic radiation of the third wavelength range, if applicable. In such a way, a white light emitting semiconductor device can be produced.

According to an embodiment of the device, side faces of the semiconductor chip are also covered with the light-

transmitting resin layer and with the wavelength converting powder layer. Particularly preferably, the side faces and the light-transmitting resin layer are in direct contact with each other. Also, the powder layer is preferably in direct
5 contact with the light-transmitting resin layer in the region of the side faces of the semiconductor chip.

The coverage of the side faces of the semiconductor chip with the light-transmitting resin layer and the powder layer lead
10 advantageously to a more homogenous radiation characteristic of the optoelectronic device.

Features and developments described in connection with the method can be also embodied by the semiconductor device and
15 vice versa.

Preferred embodiments and developments of the method and the semiconductor device are described in the following in connection with the Figures.

20

With the help of the schematic sectional views of Figures 1 to 5 an embodiment of the method is explained in further detail.

25 Figure 5 shows the finished semiconductor device according to an embodiment of the invention.

Equal or similar elements as well as elements of equal function are designated with the same reference signs in the
30 figures. The figures and the proportions of the elements shown in the figures are not regarded as being shown to scale. Rather, single elements, in particular layers, can be

shown exaggerated in magnitude for the sake of better presentation.

In a first step, a semiconductor chip 1 is provided on a
5 carrier 2 (Figure 1). The semiconductor chip 1 comprises an
active layer 3, which is configured to generate blue light
during the operation of the semiconductor chip 1. The blue
light is emitted from a radiation exit surface 4 of the
semiconductor chip 1. A bond wire 5 connects the
10 semiconductor chip 1 electrically to the carrier 2.

In a next step, a resin mixture 6 is deposited on the
radiation exit surface 5 of the semiconductor chip 1 by
jetting as schematically shown in Figure 2. The resin mixture
15 6 comprises silicone or is formed by silicone. The resin
mixture 6 can be homogenized by centrifugation.

The resin mixture 6 forms a thin light-transmitting resin
layer 7, which covers the radiation exit surface 5 of the
20 semiconductor chip 1 as well as the side faces 8 of the
semiconductor chip 1 as shown in Figure 3. The light-
transmitting resin layer 7 transmits the electromagnetic
radiation generated by the active layer 3 of the
semiconductor chip 1. Particularly preferably, the light-
25 transmitting resin layer 7 is transparent for the radiation
generated by the semiconductor chip 1. For example, the
light-transmitting resin layer 7 is transparent for visible
light.

30 In a next step, a surface 9 of the light-transmitting resin
layer 7 is coated with a powder layer 10 formed by phosphor
particles (Figure 4). According to the present embodiment,
the coating of the surface 9 of the light-transmitting resin

layer 7 is performed by electrostatic spraying with the help of a powder gun 11. The powder gun 11 is moved in a lateral direction as indicated by the arrow over the surface 9 of the light-transmitting resin layer 7 during the deposition process.

During the electrostatic powder deposition, a thin layer of phosphor particles 12 is deposited on the surface 9 of the light-transmitting resin layer 7. The phosphor particles 12 form the powder layer 10. The powder layer 10 covers the surface 9 of the light-transmitting resin layer 7 particularly preferably completely. The light-transmitting resin layer 7 has adhesive properties and fixes the phosphor particles 12 of the powder layer 10 on the surface 9 of the light-transmitting resin layer 7.

The phosphor particles 12 convert light of the first wavelength range in light of the second wavelength range, preferably in yellow light. It is also possible that the powder layer 10 comprises a further kind of phosphor particles 12, which converts light of the first wavelength range in light of a third wavelength range.

Finally, the light-transmitting resin layer 7 is cured.

The finished optoelectronic device is shown schematically in Figure 5. The optoelectronic device according to the embodiment of Figure 5 comprises a carrier 2 onto which a semiconductor chip 1 is mounted. The semiconductor chip 1 emits light of a first wavelength range from its radiation exit surface 4 during operation. Preferably, the semiconductor chips 1 emits blue light.

A light-transmitting resin layer 7 is arranged over the entire semiconductor chip 1. For example, the light-transmitting resin layer 7 is formed of silicone. The light-transmitting resin layer 7 embeds the semiconductor chip 1 completely, such that there is no external access to the semiconductor chip 1. Therefore, also side faces 8 of the semiconductor chip 1 are covered with the light-transmitting resin layer 7.

On a surface 9 of the light-transmitting resin layer 7, a powder layer 10 of phosphor particles 12 is arranged in direct contact. The powder layer 10 covers the surface 9 of the light-transmitting resin layer 7 completely. The powder layer 10 is formed of phosphor particles 12, which convert a part of the blue light emitted by the semiconductor chip 1 in light of a different wavelength range, at the present in yellow light.

The optoelectronic device of Figure 5 emits radiation consisting of unconverted light of the first wavelength range emitted by the semiconductor chip 1 and converted light of the second wavelength range. Particularly preferably, the color locus of the mixed light emitted by the optoelectronic device of Figure 5 is in the white region of the CIE norm diagram.

The invention is not limited to the description of the embodiments. Rather, the invention comprises each new feature as well as each combination of features, particularly each combination of features of the claims, even if the feature or the combination of features itself is not explicitly given in the claims or embodiments.

Claims (We claim)

1. Method for producing an optoelectronic device comprising the steps:

- 5 - providing a semiconductor chip (1), which emits electromagnetic radiation of a first wavelength range from a radiation exit surface (4) during operation,
- coating at least the radiation exit surface (4) with a light-transmitting resin layer (7),
10 - coating a surface (9) of the light-transmitting resin layer (7) with a powder layer (10) comprising phosphor particles (12), wherein the phosphor particles (12) are configured to convert the light of the first wavelength range in electromagnetic radiation of a second wavelength range, and
15 - curing the light-transmitting resin layer (7).

2. The method of the preceding claim, wherein the radiation exit surface (4) is coated with the light-transmitting resin (7) layer by jetting.

20

3. The method of one of the preceding claims, wherein the surface (9) of the light-transmitting resin layer (7) is coated with the phosphor particles (12) by electrostatic deposition.

25

4. The method of one of the preceding claims, wherein the light-transmitting resin layer (7) acts as adhesive for the powder layer (10).

- 30 5. The method of one of the preceding claims, wherein the powder layer (10) comprises further phosphor particles, which convert the light of the first wavelength range in electromagnetic radiation of a third wavelength range.

6. The method of one of the preceding claims, wherein
- a resin mixture (6) is provided for coating the radiation
exit surface (4) of the semiconductor chip (1), and
- the resin mixture (6) is homogenized by centrifugation
5 before coating the radiation exit surface (4).

7. The method of one of the preceding claims, wherein
- a phosphor mixture is provided for coating the surface (9)
of the light-transmitting resin layer (7), and
10 - the phosphor mixture is homogenized by centrifugation
before coating the surface (9) of the light-transmitting
resin layer (7).

8. The method of one of the preceding claims, wherein the
15 light-transmitting resin layer (7) is free of wavelength
converting properties.

9. The method of one of the preceding claims, wherein the
semiconductor chip (1) is provided on a carrier (2).
20

10. The method of one of the preceding claims, wherein
- a plurality of semiconductor chips (1) are provided on a
common carrier (2), and
- said semiconductor chips (1) are covered sequentially with
25 the light-transmitting resin layer (7).

11. The method of one of the preceding claims, wherein the
semiconductor chip (1) is molded with a further resin.

30 12. Optoelectronic semiconductor device with:
- a semiconductor chip (1) with an active layer (3)
generating electromagnetic radiation of a first wavelength
range during operation of the semiconductor chip (1), said

radiation is emitted from a radiation exit surface (4) of the semiconductor chip (1),

- a light-transmitting resin layer (7) on the radiation exit surface (4) of the semiconductor chip (1),

- 5 - a powder layer (10) on the light-transmitting resin layer (7), said powder layer (10) comprises phosphor particles (12), which convert radiation of the first wavelength range in electromagnetic radiation of a second wavelength range.

- 10 13. The optoelectronic device of the preceding claim, wherein side faces (8) of the semiconductor chip (1) are also covered by the light-transmitting resin layer (7) and by the powder layer (10).

FIG 1

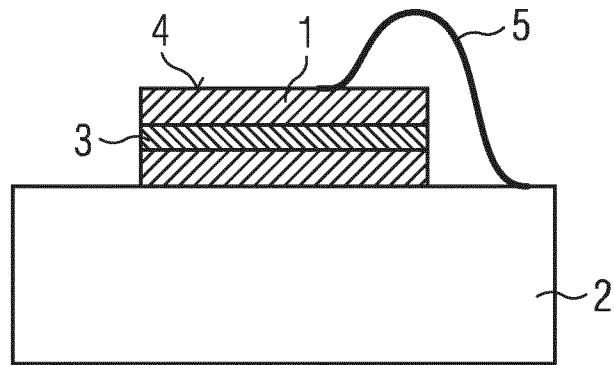
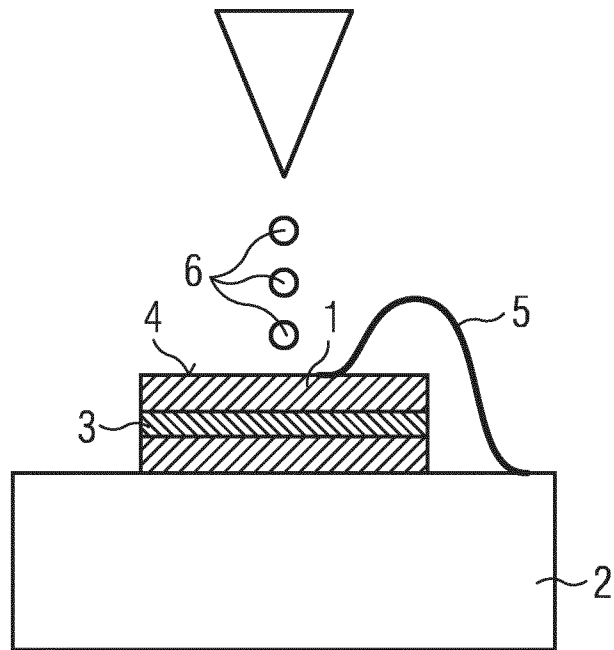


FIG 2



2/2

FIG 3

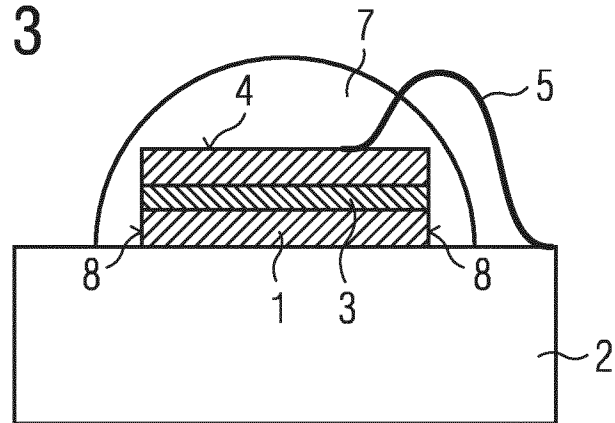


FIG 4

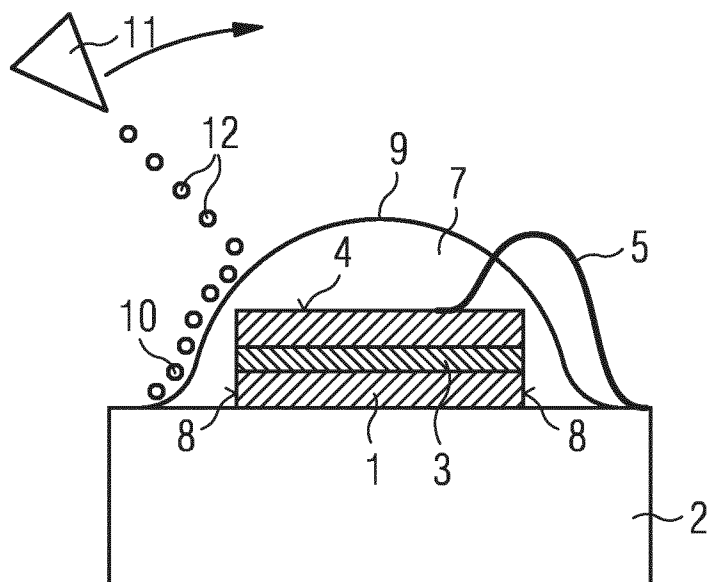
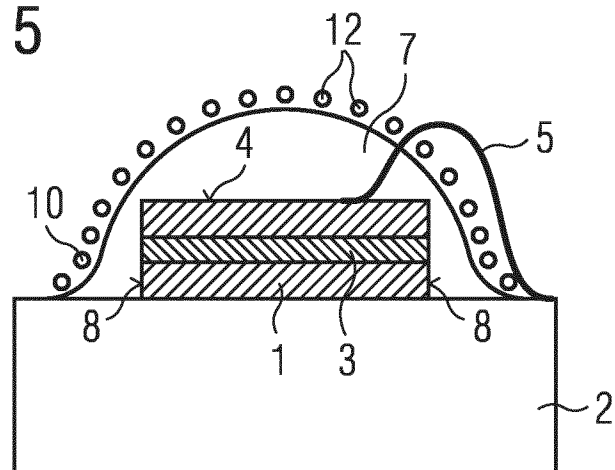


FIG 5



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/051843

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01L33/50

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2003 197977 A (OKAYA ELECTRIC INDUSTRY CO) 11 July 2003 (2003-07-11) abstract; figure 3 -----	1,3,4,8, 9,11,12 2,5-7, 10,13
X	US 2013/285096 A1 (TSENG YU-FANG [TW] ET AL) 31 October 2013 (2013-10-31) paragraphs [0010] - [0022]; figures 1-5 -----	1-13
X A	DE 10 2004 022648 A1 (ZUMTOBEL AG DORNBIRN [AT]) 15 December 2005 (2005-12-15) claims; figures 1-3 -----	1,4,8,9, 11-13 2,3,5-7, 10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/051843

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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