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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 July 2009 (16.07.2009)

PCT

(10) International Publication Number
WO 2009/087584 A1

(51) International Patent Classification:
*F21V 14/00* (2006.01) *H01L 33/00* (2006.01)
*F21K 7/00* (2006.01) *G02F 1/13357* (2006.01)
*B32B 17/10* (2006.01)

(21) International Application Number:
PCT/IB2009/050007

(22) International Filing Date: 5 January 2009 (05.01.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
08100190.1 8 January 2008 (08.01.2008) EP

(71) Applicant *(for all designated States except US)*: **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **HIKMET, Rifat, A., M.** [CY/NL]; c/o High Tech Campus, building 44, NL-5656 AE Eindhoven (NL). **VAN BOMMEL, Ties** [NL/NL]; c/o High Tech Campus, building 44, NL-5656 AE Eindhoven (NL).

(74) Agents: **BEKKERS, Joost, J., J.** et al.; c/o High Tech Campus, building 44, NL-5656 AE Eindhoven (NL).

(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, 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, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (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, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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

**Published:**
— *with international search report*

(54) Title: LIGHT OUTPUT DEVICE WITH SWITCHABLE REFRACTIVE ELEMENTS

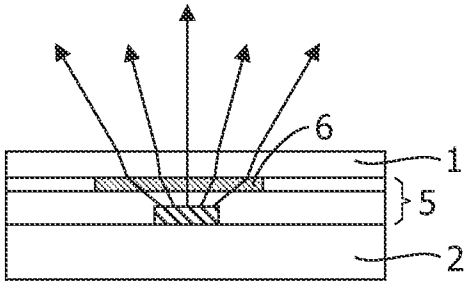



FIG. 4B

(57) Abstract: Alight output device comprises a substrate arrangementcomprisingfirst and second substrates(1,2), and an insulating layer (5) between the substrates. Atleast one light source (4) is provided within the substrate arrangement, withthe light output passing into the insulating layer (5). The insulating layer has portions (6) of different refractive index in the vicinity of the light source, thereby defining an optical output function for the light output of the light source. This arrangement uses the insulating layer (5) between the substrates as an optical output device, to provide a desired optical output function.

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# LIGHT OUTPUT DEVICE WITH SWITCHABLE REFRACTIVE ELEMENTS

## FIELD OF THE INVENTION

This invention relates to light output devices, particularly but not exclusively using discrete light sources associated with a transparent substrate structure.

## BACKGROUND OF THE INVENTION

One known example of this type of light output device is a so-called "LED in glass" device. An example is shown in Figure 1. Typically a glass plate is used, with a transparent conductive coating (for example ITO) forming electrodes. The conductive coating is patterned in order to make the electrodes that are connected to a semiconductor LED device. The assembly is completed by laminating the glass, with the LEDs inside a thermoplastic layer (for example polyvinyl butyral, PVB) or organic resin layer.

Applications of this type of device are shelves, showcases, facades, office partitions, wall cladding, and decorative lighting. The light output device can be used for illumination of other objects, for display of an image, or simply for decorative purposes.

Top emitting LEDs can be used, and these have a spot light source output. Side emitting LEDs can also be used, the light output then being coupled to the output from scattering centres in the resin.

However, there remain difficulties in providing a desired output from the discrete light sources, in terms of illumination direction and illumination spot size.

## SUMMARY OF THE INVENTIONS

According to the invention, there is provided a light output device comprising:

- a substrate arrangement comprising first and second substrates;
- an insulating layer arrangement between the substrates; and
- at least one light source within the substrate arrangement, with the light output passing into the insulating layer arrangement,

wherein the insulating layer arrangement has portions of different refractive index in the vicinity of the light source, thereby defining an optical output function for the light output of the light source.

This arrangement uses the insulating layer between the substrates as an optical output device, to provide a desired optical output function.

The device preferably further comprises an electrode arrangement provided within the substrate arrangement and comprising at least semi-transparent electrodes, wherein the at least one light source is electrically driven by the electrodes. There is preferably an array of light sources, each associated with a respective set of portions of different refractive index of the insulating layer.

Different optical functions can be implemented as refractive index patterns within the layer. For example, the optical function can comprise:

- a lens function, or
- an increased optical output at selected regions in the vicinity of the light source compared to other regions in the vicinity of the light source (i.e. a function of changing the output shapes), or
- a light output direction from the light source.

In one example, the insulating layer comprises a photo refractive resin.

In another example, the insulating layer comprises a liquid crystal element, which is switchable between a light redirection mode, in which the insulating layer has refractive index variations, and a transparent mode, in which the insulating layer has uniform refractive index and does not perform a light redirection function. The light redirection mode may be induced by applying an electric field. This enables the output function to be switchable.

The liquid crystal element can for example define a graded refractive index lens element in the vicinity of the light source.

In another example, the liquid crystal element comprises a switchable liquid crystal portion and a non-switchable replica portion. The switchable portion enables a changeable refractive index boundary to be defined between the switchable portion and the replica portion.

In another example, the liquid crystal element comprises a liquid crystal gel which can be switched to the light redirection mode.

The gel can have different sections which switch to the light redirection mode at a different voltage.

Each light source can comprise an LED device or a group of LED devices.

The invention also provides a method of manufacturing a light output device, comprising:

- providing a substrate arrangement comprising first and second substrates with a photo refractive resin layer between the substrates and at least one light source within the substrate arrangement embedded in the photo refractive resin layer; and
- photo activating the photo refractive resin layer to define portions of different refractive index within the photo refractive resin layer in the vicinity of the light source, thereby defining an optical output function for the light output of the light source.

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

## BRIEF DESCRIPTION OF THE DRAWINGS

Examples of the invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 schematically shows a known LED in glass illumination device;

Figure 2 schematically shows an example of the structure of the device of Figure 1;

Figures 3A and 3B schematically show how illumination can be focused to cause refractive index changes in a method of the invention;

Figures 4A and 4B compare the optical output of a conventional device with a first example of device of the invention;

Figures 5 to 10 schematically show different optical output effects that can be obtained using the device of the invention;

Figures 11A and 11B schematically show the optical output of a second example of device of the invention in two different modes of operation; and

Figures 12A and 12B schematically show the optical output of a third example of device of the invention in the two different modes of operation.

The same reference numerals are used to denote similar parts throughout the Figures.

## DETAILED DESCRIPTION OF EMBODIMENTS

Figure 2 shows a known LED in glass structure. The light output device comprises glass plates 1 and 2. Between the glass plates are (semi-) transparent electrodes 3a and 3b (for example formed using ITO or thin conductive wires), and an LED 4 connected to the transparent electrodes 3a and 3b. A layer of insulating material 5 is provided between glass plates 1 and 2 (conventionally PVB or UV resin).

When transparent electrodes are used, they are not visible to the viewer, and they do not introduce non-uniformities to the light output.

The electrodes are preferably substantially transparent, by which is meant that they are imperceptible to a viewer in normal use of the device. If the conductor arrangement does not introduce a noticeable variation in light transmission (for example because it is not patterned, or because the pattern cannot be seen), a transparency of greater than or equal to 50% may be sufficient for the system to appear transparent. More preferably, the transparency is greater than 70%, more preferably 90%, and even more preferably 99%. If the conductor arrangement is patterned (for example because thin wires are used), the transparency is preferably greater than 80%, more preferably 90%, but most preferably greater than 99%.

The electrodes can be made of a transparent material such as ITO or they can be made of an opaque material such as copper but be sufficiently thin so that they are not visible in normal use. Examples of suitable materials are disclosed in US-A-5 218 351.

A particularly useful opaque conductive material may be a conductive ink deposited using silkscreen or inkjet printing, because this allows the conductor arrangement to be deposited in a cost-effective manner.

The glass plates typically may have a thickness of 1.1mm - 2.1 mm. The spacing between electrode is typically 0.01 – 3 mm, for example around 0.15 mm. The thermoplastic layer has a thickness of 0.5mm- 2mm, and the electrical resistance of the electrodes is in the range 1 - 80 Ohm, or 1-50 Ohm or more preferably 2-20 Ohm, or 10-30 Ohms/square.

The invention provides an insulating layer which has portions each having different refractive index to provide an optical output function for the light output of the light source.

One example of the invention uses a photo refractive resin to define an optical component. Figure 3A shows a single focused beam used to photo-induce the refractive index change in the insulating layer 5, and Figure 3B shows the interference of two or more laser beams within the layer 5 leading to intensity fluctuations which in turn induce refractive index fluctuations.

Figures 3A and 3B thus show two different ways of inducing refractive index change, one of which uses focusing of a single beam, and the other of which uses interference between two beams.

A first example uses a refractive index profile to define a lens function, so that the beam paths change from those shown in Figure 4A to those shown in Figure 4B. The output is more collimated and there is less light loss through total internal reflection with the surface of the top substrate.

In Figure 4B, the insulating layer 5 has portions 6 with a certain refractive index profile in the vicinity of the light source 4. The refractive index profile may be in the form of a refractive index gradient along the thickness of the layer or it may be in the form of a phase grating in the plane of the layer giving rise to a diffractive lens working function.

The lens function effectively changes the size of the output spot, but it can also be used to change the light output direction. The distribution of light within the device can also be optimised.

The device of Figure 4B again uses a substrate arrangement with first and second substrates 1,2, with an array of LEDs 4. The electrode arrangement is not shown in Figure 4B to make the diagrams simpler.

Partially cured or uncured photo curable resins such as acrylates, and materials which show photo isomerisation, are some of the examples of such photo refractive materials. Materials which change their refractive index due to local heating or bleaching of a component, when under intense beams, can also be considered as photo refractive materials.

A simple way to create a lens function induced into a diffractive element is to use a layer of linear polymer containing a photo curable component. A laser beam can be split into two components. A lens is then placed in the path of one of the beams focusing light onto a plane, and the beam is combined with the other beam causing them to interfere. When the layer of polymer with a reactive component is placed at this plane, the interference pattern leads to the formation of a refractive index pattern as the reactive component diffuses and polymerizes in the high light intensity areas. A flood exposure is then applied in order to fix the refractive index pattern which in turn functions as a lens.

Figures 5 to 10 show different optical output effects that can be obtained using the device of the invention.

In Figure 5, regions 6 are used to out-couple light from parts of the surface away from the LEDs 4. These can give a random pattern, or a regular pattern as in Figure 6. Such structures can have the form of a grating. Such a grating then selectively diffracts a certain wavelength coming from a certain direction according to well known diffraction theory, with the result that selective wavelengths are provided as output at the location of the structure.

Figure 7 shows round lens arrays 6 and Figure 8 shows oval (asymmetrical) lens designs.

Figure 9 shows line-shaped out-coupling structures.

Figure 10 shows that by individually driving the LEDs, different illumination directions or shapes can be obtained. Figures 10A to 10C schematically show three different LEDs 4a,4b,4c being turned on, with the light output direction being different in each case as a result of the local refractive index arrangement.

For example it is possible to adjust the direction of out-coupling by adjusting the direction of a phase grating induced in the photo refractive material. In Figure 8, the pattern 6 is in the form of concentric ellipsoidal grating patterns, and this pattern provides a directional output. The direction of the ellipsoidal grating pattern placed around the LED 6 then determines the shape of the light coupled out of the LED.

In the examples above, a refractive index pattern is fixed into the structure of the insulator layer. In another set of examples, the refractive index pattern is switchable.

Figure 11 shows a structure of first and second substrates 1,2, with an insulating layer arrangement between them, which consists of the resin layer 5 with embedded LED 4, and an LC layer 10. Within the LC layer, refractive index variations can be induced by application of an electric field. The transparent electrodes are not shown for the sake of clarity.

An advantage of the use of a continuous switchable LC layer as shown (compared to a polymer dispersed liquid crystal layer, PDLC) is that when no field is applied (Figure 11A), there is no light scattering in the direction parallel to the substrate or perpendicular to the substrate. In the mode of operation with no field, the LC layer has uniform refractive index and does not alter the direction of light. This makes the device particularly suitable for use in secrecy window applications. In the field-off state, there is good transparency in all directions through the device as shown by the arrows in Figure 11A which represent the undisturbed passage of light through the device in the directions perpendicular and parallel to the substrate.

Figure 11B shows the electric field applied, providing a state in which refractive index variations are induced. Increasing the electric field enables the system to become increasingly light scattering.

The device of Figure 11 can for example be implemented using liquid crystal gels. There are also kinds of liquid crystal gels which can be patterned to give regions which switch at different voltages. When such gels are used in the field-off state, the system again

has uniform refractive index. Application of an electric field across such a gel again induces refractive index fluctuations altering the path of light going through the gel, and different regions can be induced to switch at different applied electric fields.

It is also possible to induce a gradient in the refractive index (GRIN) within the liquid crystal layer. Such a gradient can be obtained in various ways. One of the possibilities is to use structured electrodes with areas containing no electrodes. When a cell is produced with such electrodes, electric field lines leak into areas with no electrodes inducing electric field gradients and hence a gradient in the refractive index of the liquid crystal in a certain direction. This type of GRIN lens is described in WO2007/007242, which is incorporated herein by reference.

The GRIN lenses can also be formed by providing interdigitating in-plane electrodes across which an electric field is applied. The field lines form a curve between the electrodes, and this electric field is used to align the LC material into a curved lens shape. The in-plane electrodes can be formed on top of the insulating layer 5 in which the LED is embedded, so that the structure has two electrode layers, one for controlling the LEDs and one for controlling the electric field in the LC layer. Electrically switchable GRIN lenses formed from LC material will be known to those skilled in the art from other applications.

As shown, an optical output function is defined in the direction perpendicular to the substrate, and there is also scattering in the direction parallel to the substrate, as shown.

In an alternative arrangement shown in Figure 12, the layer 10 comprises a non-switchable replica portion 12 and a switchable LC portion 14. The electrodes (not shown in this figure), in order to apply a voltage across the layer 10, can be placed at the inner surfaces of the substrates 1 and 2.

There is again a mode with no light redirection (Figure 12A). In this mode the refractive index of the LC material is matched in all the directions with the refractive indices of the replica material. There is again good transparency in all directions through the device, so that it is suitable for window applications. In the electric field-on state (Figure 12B), the orientation direction of the LC molecules is altered and there is a refractive index change at the interface of the LC and the replica. In this case, the path of the light is altered by the resulting lens function.

In the example shown in Figure 12, the replica has the shape of a lens. However the structures may also have other shapes such as grating, blazed grating, pyramids, rectangular gratings etc.

The control of the output function can be automated, for example based on the signal detected by movement sensors.

The invention is of particular interest for signage, decorative lighting such as lamps, windows, architectural glass, and secrecy windows, although other applications are possible, such as furniture and other decorative items. The device of the invention can be used to produce logos or text in addition to the lighting effects discussed above.

Various other possibilities are within the scope of the various aspects of the invention, as defined by the attached claims.

Various other modifications will be apparent to those skilled in the art.

CLAIMS:

1. A light output device comprising:
- a substrate arrangement comprising first and second substrates (1,2);
- an insulating layer arrangement (5) between the substrates (1,2); and
- at least one light source (4) within the substrate arrangement, with the light output passing into the insulating layer arrangement (5),
wherein the insulating layer arrangement (5) has portions (6) of different refractive index in the vicinity of the light source, thereby defining an optical output function for the light output of the light source (4).

2. A device as claimed in claim 1, further comprising an electrode arrangement (3a,3b) provided within the substrate arrangement and comprising at least semi-transparent electrodes, wherein the at least one light source (4) is electrically driven by the electrodes.

3. A device as claimed in any preceding claim, comprising an array of light sources (4), each associated with a respective set of portions (6) of different refractive index of the insulating layer.

4. A device as claimed in any preceding claim, wherein the optical function comprises a lens function and/or acts as a grating.

5. A device as claimed in any one of claims 1 to 3, wherein the optical function comprises an increased optical output at selected regions in the vicinity of the light source (4) compared to other regions in the vicinity of the light source.

6. A device as claimed in any one of claims 1 to 3, wherein the optical function comprises a light output direction from the light source.

7. A device as claimed in any preceding claim, wherein the insulating layer (5) comprises a photo refractive resin.

8. A device as claimed in any one of claims 1 to 6, wherein the insulating layer (5) comprises a liquid crystal element (10), which is switchable between a light redirection mode, in which the insulating layer has refractive index variations, and a transparent mode, in which the insulating layer has uniform refractive index and does not perform a light redirection function.

9. A device as claimed in claim 8, wherein the liquid crystal element (10) can be switched into the light redirection mode under the influence of an applied electric-field.

10. A device as claimed in claim 8, wherein the liquid crystal element (10) comprises a switchable liquid crystal portion (14) and a non-switchable replica portion (12).

11. A device as claimed in claim 8, wherein the liquid crystal element (10) comprises a liquid crystal gel which can be switched to the light redirection mode.

12. A device as claimed in claim 11, wherein the liquid crystal gel has different sections which switch to the light redirection mode at a different voltage.

13. A device as claimed in any preceding claim, wherein each light source (4) comprises an LED device.

14. A device as claimed in any preceding claim, wherein each light source (4) comprises a group of LED devices.

15. A method of manufacturing a light output device, comprising:
providing a substrate arrangement comprising first and second substrates (1,2) with a photo refractive resin layer (10) between the substrates (1,2) and at least one light source (4) within the substrate arrangement embedded in the photo refractive resin layer (10); and
photo activating the photo refractive resin layer (10) to define portions of different refractive index within the photo refractive resin layer (10) in the vicinity of the at least one light source (4), thereby defining an optical output function for the light output of the light source (4).

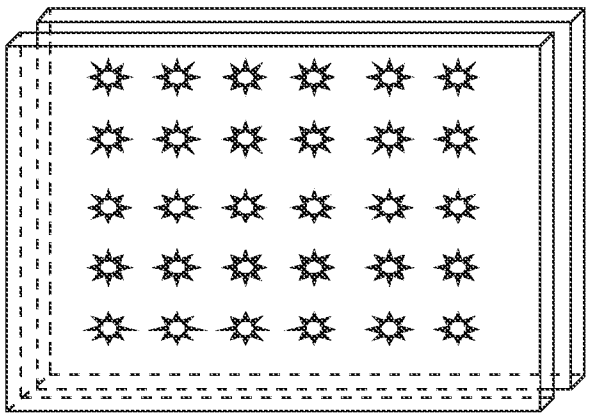


FIG. 1

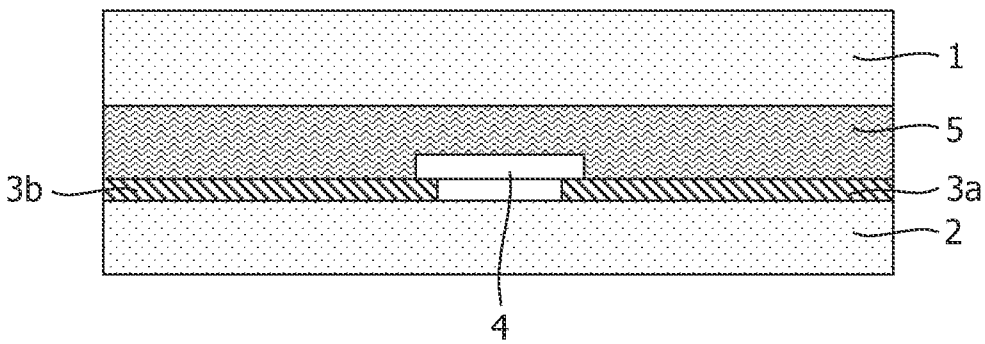



FIG. 2

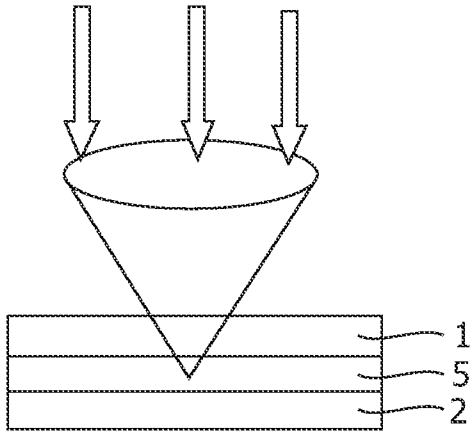



FIG. 3A

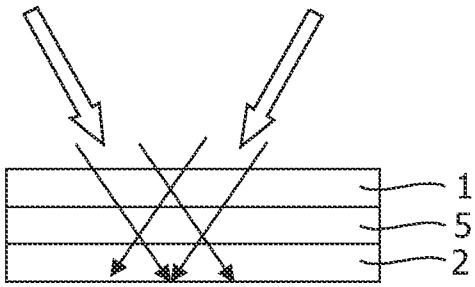



FIG. 3B

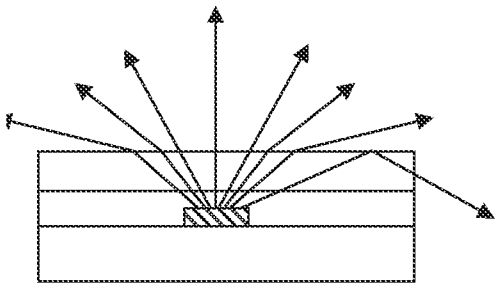


FIG. 4A

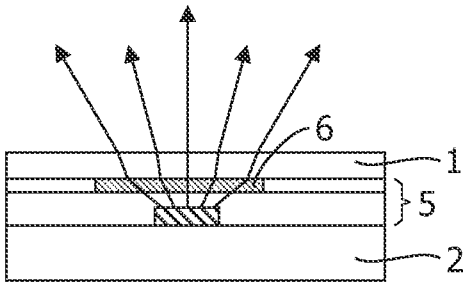



FIG. 4B

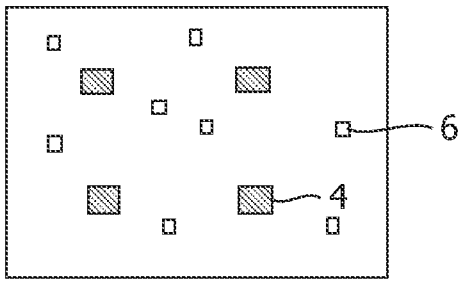



FIG. 5

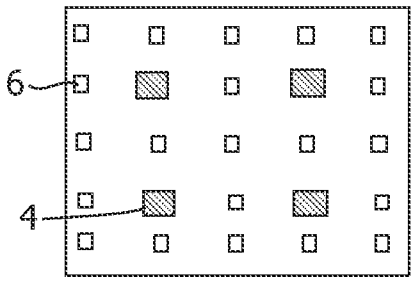



FIG. 6

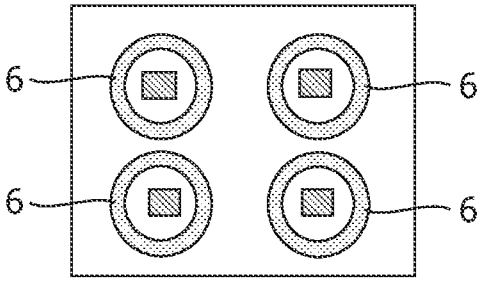



FIG. 7

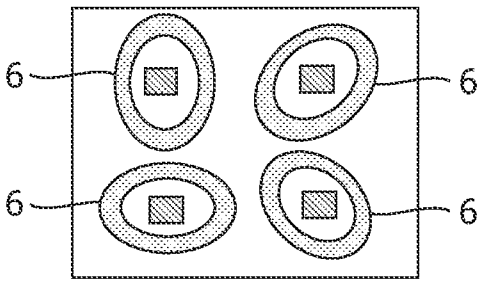



FIG. 8

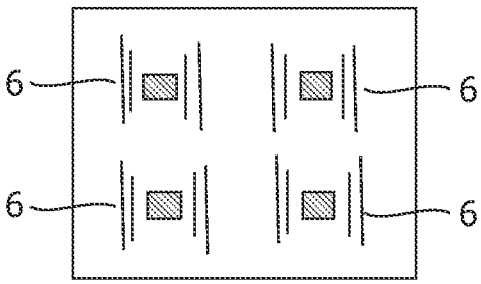



FIG. 9

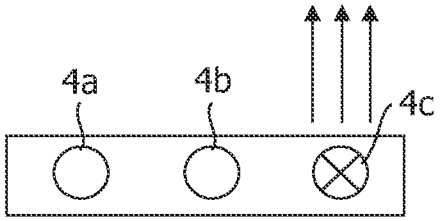



FIG. 10A

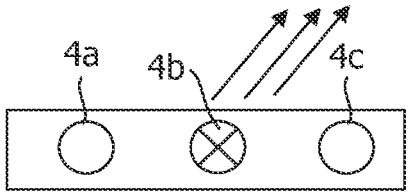



FIG. 10B

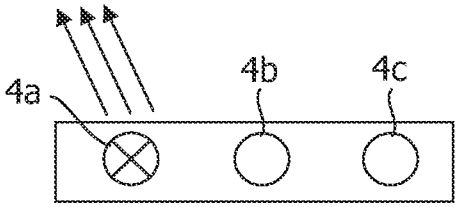



FIG. 10C

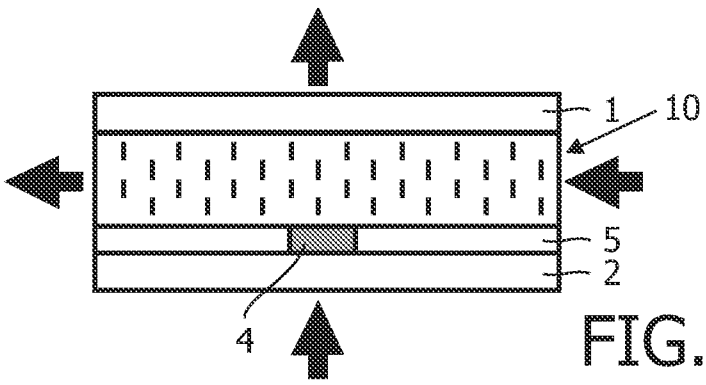



FIG. 11A

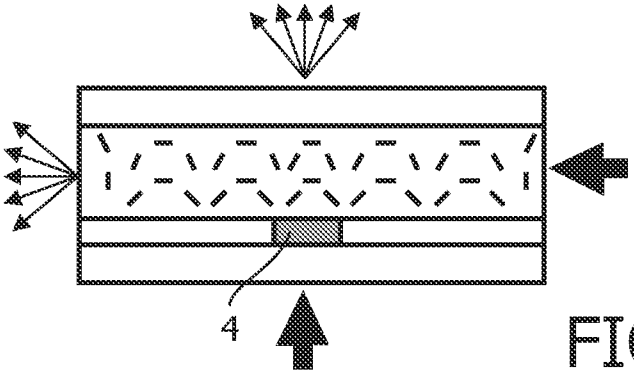



FIG. 11B

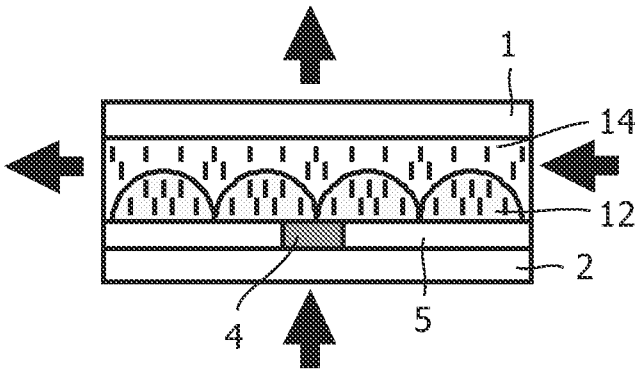



FIG. 12A

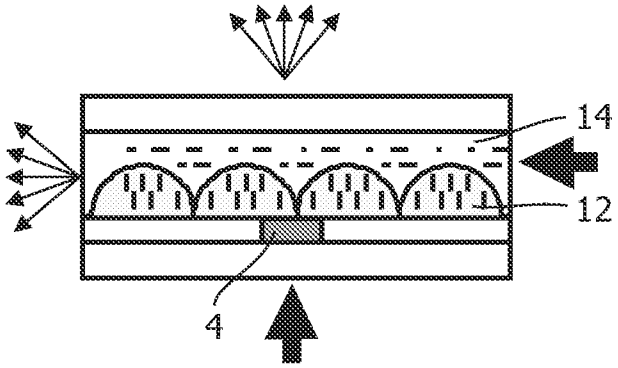



FIG. 12B

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/050007

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21V14/00 F21K7/00 B32B17/10 H01L33/00 G02F1/13357

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)
F21V F21K B32B H01L G02F G09F

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)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br><br><br>Y | WO 2007/077239 A (PILKINGTON AUTOMOTIVE D GMBH [DE]; DERDA MARTIN [DE])<br>12 July 2007 (2007-07-12)<br>pages 1-7; figures<br><br>pages 11-12 | 1-6,<br>8-10,13,<br>14<br>7,11,12,<br>15 |
| Y | WO 2007/007235 A (KONINKL PHILIPS ELECTRONICS NV [NL]; PHILIPS INTELLECTUAL PROPERTY [DE) 18 January 2007 (2007-01-18)<br>page 19, line 14 - page 20, line 13;<br>figures | 7,11,12,<br>15 |

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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 | Date of mailing of the international search report |
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| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Chaloupy, Marc |

# INTERNATIONAL SEARCH REPORT

International application No
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Information on patent family members

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