

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
3 January 2008 (03.01.2008)

PCT

(10) International Publication Number  
**WO 2008/001241 A2**

(51) International Patent Classification: **Not classified**

(21) International Application Number:  
PCT/IB2007/052085

(22) International Filing Date: 4 June 2007 (04.06.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
06115469.6 14 June 2006 (14.06.2006) EP

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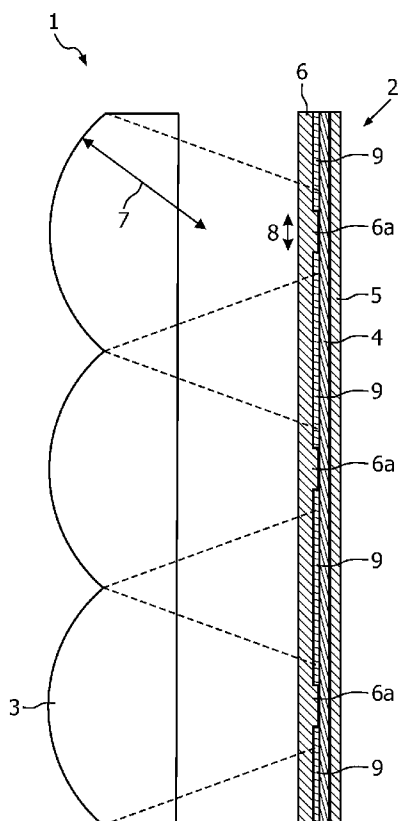
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(81) Designated States (unless otherwise indicated, for every  
kind of national protection available): AE, AG, AL, AM,  
AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH,  
CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG,  
ES, FI, GB, GD, GE, 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, 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, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL,  
PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM,  
GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(54) Title: STRUCTURED OLED WITH MICRO OPTICS FOR GENERATING DIRECTED LIGHT



(57) Abstract: In a lighting device with at least one continuous OLED layer (4) with a first electrode layer (5), a second electrode layer (6) and a plurality of optical collimating means, the second electrode layer (6) is only in electrical contact with the OLED layer (4) within spaced sections (6a), arranged within acceptance angles of the collimating means. Such a lighting device can be manufactured efficiently and is highly energy- efficient.



**Published:**

— without international search report and to be republished upon receipt of that report

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## STRUCTURED OLED WITH MICRO OPTICS FOR GENERATING DIRECTED LIGHT

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The invention relates to a lighting device with an organic light-emitting device (OLED).

Organic light emitting devices are today readily available for integration into lighting or display products. The OLED technology is especially advantageous,  
10 since it enables the manufacture of lighting devices, which irradiate from a relatively large surface area, while can be made extremely thin.

An OLED exhibits a lambertian radiation pattern, resulting in a large beam divergence. For display applications, for example when using an OLED layer as a light source for a display panel, the lambertian radiation pattern is advantageous. On the  
15 other hand, for lighting or signalling applications, as for example in automobile applications, a directed beam is usually required. Because of the law of etendue conservation, it is problematic to collimate light of large-area light emitters, such as OLEDs.

20

The document EP 1 051 582 discloses a lighting device, showing a large-area light emitter. To collimate the generated light, a plurality of transparent light-directing members are provided. On said light-directing members, a plurality of semiconductor lighting devices, such as OLEDs, are arranged. Each semiconductor  
25 lighting device emits light into the respective light-directing member, which is then collimated, so that a predefined beam shape can be generated. Although this solution enables the construction of a lighting device, emitting directed light from a large-area light emitter, the manufacture of such device with a plurality of OLEDs is very complex and expensive.

It is therefore an object of the current invention to provide an OLED lighting device, which enables a directed beam to be generated and which can be  
5 manufactured efficiently and inexpensively. The object is solved according to the invention by a lighting device according to claim 1. Dependent claims relate to preferred embodiments of the invention.

According to the invention, at least one continuous OLED layer is sandwiched between a first and second electrode layer, which electrode layers  
10 electrically contact to respective first and second surfaces of the OLED layer. To generate a directed beam of light, optical collimating means are provided, spaced from the OLED layer by at least the second electrode layer. Each of the collimating means define an acceptance angle, in which light is accepted by the collimating means to form an directed output beam of light. In the present invention, the acceptance angle of each  
15 of the collimating means forms an acceptance area on the OLED layer, from where light, generated in the OLED layer is accepted by the collimating means. In the context of the present invention, the term acceptance angles refers to the plurality of angular ranges, defined by the plurality of collimating means.

The second electrode layer is advantageously only in electrical contact  
20 with the OLED layer in spaced sections, which are each within the acceptance angle of the respective collimating means. Thus, the emission of light within the OLED layer is only stimulated within the acceptance angles. While the invention advantageously allows the use of a continuous OLED layer, light is not generated in areas of the OLED layer, where light could not be accepted by the collimating means and thus would not  
25 contribute to form the directed output beam. In the context of the present invention one or more sections can be formed in the acceptance angle of each of the collimating means.

The term "OLED layer" is in the context of the present invention understood to include the necessary emitter (EL), electron transport (ETL) and hole  
30 transport layers (HTL), as well as any other eventually necessary layer, depending on the OLED technology used.

Within OLED structures, light is generated by the recombination of electron/hole pairs in the EL layer, which are introduced in the OLED layer. Usually suitable electrodes are arranged laminar on the surfaces of the OLED to introduce the electron/hole pairs. The energy, released by the recombination of an electron/hole pair  
5 generates an exciton, which stimulates a molecule within the EL layer to emit a photon at the desired wavelength and thus generates the desired coloured light.

The OLED layer may be formed of any commercially available OLED material, including SM-OLEDs (small-molecule OLED's) and PLEDs (polymer-light-emitting-diodes).

10 The OLED layer is electrically contacted by said first and said second electrode layers. In terms of the present invention, said second surface of the OLED layer shall be defined as the light emitting surface. To enable a sufficient efficacy of the lighting device, the second electrode layer therefore is at least partially transparent in the desired wavelength-range. For example, the second electrode layer may be formed from  
15 indium-tin-oxide (ITO), which is transparent in the visible wavelength range. The first electrode layer does not need to be transparent and may be formed for example from a metal or a metal alloy. Preferably, the surface of the first electrode layer, which contacts to said first surface of the OLED layer should be reflective in the desired wavelength-range to enable an even higher efficacy of the lighting device.

20 To enable the formation of a defined output beam, a plurality of optical collimating means are arranged on the side of the second surface of the OLED layer, i.e. the light-emitting surface, spaced from the OLED layer by at least said second electrode layer. The plurality of optical collimating means collimate the light, emitted by the OLED layer. The collimating means may be formed to collimate light only in one axis,  
25 perpendicular to the optical axis of the lighting system or preferably to collimate light in two axes, each perpendicular to the optical axis, according to the specific application. In terms of the present invention, the optical axis is defined perpendicular to and in the center of the second surface of the OLED layer.

The collimating means may be formed of any suitable material, preferably  
30 glass or polymer material, depending on the desired output beam shape and thus the necessary difference in refractive indices. Naturally, the material of the collimating means

should be chosen, so as not to introduce relevant losses in the desired wavelength range. The optical collimating means may preferably be formed by a plurality of lenses or microlenses or a foil of lenses or microlenses, when a polymer material is used. The use of a polymer foil is especially preferred, since such a polymer foil can be formed  
5 advantageously in a cost-effective injection moulding process. The collimating means may be for example cylindrical lenses, spherical lenses or CPC collimators (compound parabolic compressor).

It may further be possible to include simple shaped elements, which collimate the incident light, for example by using a material, in which the refractive index  
10 is varied according to the desired output beam shape. For example, such elements may be cylindrical gradient index lenses. The collimating means may comprise further collimators, lenses, lens groups, lens arrays or any combination thereof, depending on the application.

The optical properties of the plurality of the collimating means may be  
15 identical to each other, in order to form a collimated output beam with an infinite focal point. If necessary, each of the plurality of collimating means may also exhibit individual optical properties, to obtain a specifically shaped output beam. Here, each collimating means forms a part of an overall "virtual lens", which determines the specific shape of the output beam. Such "virtual lenses", formed by a plurality of single collimating  
20 elements are commonly designed using a finite elements method.

In a simple example, the outermost collimating means in a beam may be formed to direct light towards the optical axis at a defined focal point, while the inner collimating means are formed to direct light along the optical axis of the lighting device, resulting in a narrow beam at the defined focal point.

25 The optical collimating means may be formed directly on the second electrode layer or preferably within a defined proximity along the optical axis of the lighting device. In the second case, the gap between the second electrode layer and the collimating means may be filled with a material with defined refractive index, for example index matching fluid, or simply be left filled with air. An arrangement of the  
30 collimating means in a defined proximity of the second electrode layer is especially advantageous in automobile applications, where the collimating means may be formed

integrally with the top cover of the automobile lamp and thus reduces the overall cost of the automobile lamp.

Each of the plurality of optical collimating means accepts light, incident to the collimating means only within a defined acceptance angle, i.e. within a defined acceptance area on the surface of the OLED layer. According to the invention, the second electrode layer exhibits spaced sections, so that the second electrode layer is only in electrical contact with the OLED within the acceptance angle of each of the optical collimating means and not in electrical contact in between the acceptance angles.

Thus, light is only generated within the acceptance angle of each of the collimating means, since due to the formation of the second electrode layer, charge carriers are only introduced into the OLED layer within the acceptance angles. The lighting device according to the invention is therefore very energy efficient, since photons are only generated in areas, where an acceptance by the collimating means is ensured. Any photon, generated outside of the acceptance angles would not be accepted by the collimating means and therefore contribute to the loss of the lighting device directly. In a device according to the invention therefore light is only generated where needed, while no complex structuring of the OLED layer or a manufacture of multiple OLEDs is necessary.

Due to the lens transform of the collimating means, a change in the dimensions of the sections will cause a change of the numerical aperture in the output beam. Thus, the shape of the output beam can be controlled by changing the dimensions of the sections, while the optical properties of the collimating means are maintained constant. Naturally, the dimensions of each section of the second electrode layer can be chosen independently or the same, depending on the application.

For many applications, as for example automotive signalling applications, an asymmetrical beam shape is desired. It is therefore preferred, that the aspect ratio of the sections is asymmetrical.

When providing asymmetrically formed sections, it is redundant to specifically form the collimating means to the desired output beam shape, which is even more cost efficient. When forming the sections asymmetrical as explained above, standard rotation-symmetric lenses can be used. As mentioned before, due to the lens transform,

the numerical aperture of the output beam shape will show the same symmetry than the aspect ratio of the sections. For example, if the sections exhibit an aspect ratio of 2:1, the resulting beam width in the two axes perpendicular to the optical axis will also be 2°:1°.

5                   To further shape the output beam, the dimensions of each of the sections may be varied over the extend of the OLED layer. For example, the outermost sections regarding to the output beam may show smaller dimensions than the inner sections. In this case, the intensity is reduced in the outermost regions of the beam, which may be desired in automotive applications, exemplary.

10                   According to a preferred embodiment of the invention, the second electrode layer is discontinuous in between the sections, so that in these spaces, no charge carriers are introduced in the OLED layer. Such a structured electrode layer may be formed by printing techniques or by deposition through a respective mask. The thus formed single electrodes of the second electrode layer may be contacted by electrical  
15 wires using a bonding or soldering process.

                  In a further preferred embodiment of the invention, the second electrode layer is continuous over at least a plurality of sections and electrically isolated by an isolating layer in between the sections. This preferred embodiment enables a very cost-efficient manufacture of the second electrode layer, since a structuring of the electrode is  
20 not necessary. The isolating layer may be formed by any techniques, as know in the art. For example, the isolating layer may be an isolating lacquer, known from standard printed circuit boards, which is printed, painted or sprayed either on the OLED layer or the second electrode layer. Further, any isolating layer, know from standard semiconductors may be used, as long as the introduction of charge carriers in areas in  
25 between the sections can be inhibited sufficiently. It is especially preferred that the second electrode layer is continuous over all sections, which allows an even more cost-efficient manufacture.

                  The invention is hereinafter explained in detail with reference to the accompanying drawings, in which



fig. 1 shows a cross section of first embodiment of the invention,  
fig. 2 shows a second embodiment of the invention in a cross sectional  
view, and  
fig. 3 shows a further embodiment of the invention.

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Referring to fig. 1, a lighting device 1 is formed from a stacked OLED 2 and  
a collimating lens array 3. The lens array 3 is formed from PMMA  
(Polymethylmethacrylate), which is transparent in the visible wave length range. Each  
10 single lens of the lens array 3 exhibits an acceptance angle, as depicted by the dotted  
lines in fig. 1.

Spaced from the lens array 3, an OLED stack 2 is provided in a defined  
proximity. The OLED stack 2 comprises at least an OLED layer 4 and a first continuous  
electrode layer 5, which is arranged on the back side of the OLED layer 4. A second  
15 electrode layer 6 is provided on the front side of the OLED layer 4.

The second electrode layer 6 is continuous, but is only in contact with the  
OLED layer 4 within sections 6a, which are within the acceptance angles of the lenses of  
the lens array 3. In between the sections, an isolating layer 9 is present. Due to this, the  
generation of light in the OLED layer 4 is only stimulated within the acceptance angles.  
20 While the first electrode layer 5 may be manufactured from a metal, such as aluminium,  
the second electrode layer 6 is an ITO electrode (indium-tin-oxide), which is transparent  
in the visible wave length range. Although not shown, further layers may be present in  
the OLED stack 2 not shown here because of clarity reasons.

In the present embodiment, each lens of the lens array exhibits a curvature  
25 radius 7 of 2,2 mm. The distance between the OLED stack 2 and the lens array 3 is 2,3  
mm. The length of the sections 6a is 0,2 mm along the shown extension 8. Light is  
output from the lens array 3 at the side, opposite of the OLED stack 2.

A detailed view of a second exemplary OLED stack 22 is shown in a  
second embodiment of the invention according to fig. 2. Fig. 2 shows a cross section  
30 through the OLED stack 22, where the direction of the emitted light is depicted by the  
shown arrows. A glass substrate 23 is provided to mechanically support the OLED stack

22. A transparent second electrode layer is formed as an ITO electrode 24 and is in this embodiment arranged discontinuously on the glass substrate 23, so that light is only generated in the OLED stack 22 within the acceptance angles of the respective lenses. The ITO electrode 24 is electrically connected to a suitable power supply. A further connection to the power supply is provided by the first electrode layer, which is formed by an aluminium electrode 33. The complete set up of the OLED stack 22 is described in detail in the following table:

| reference no. | material                 | thickness |
|---------------|--------------------------|-----------|
| 23            | glass                    | 0,7 mm    |
| 24            | ITO electrode            | 80 nm     |
| 25            | PEDOT                    | 30 nm     |
| 26            | MTDATA                   | 20 nm     |
| 27            | Spiro-TAD                | 8 nm      |
| 28            | CBP: Flrpic              | 15 nm     |
| 29            | CBP: Irppy               | 10 nm     |
| 30            | CBP: ADS076              | 60 nm     |
| 31            | Alq 3                    | 1 nm      |
| 32            | LiF                      | 100 nm    |
| 33            | aluminium (AL) electrode | 100 nm    |

The set up explained above provides a white light organic LED.

Fig. 3 shows an exemplary set-up in a further embodiment of the invention in a plan view. The lighting device is designed to obtain an asymmetrically shaped output beam. As explained above, the OLED layer 34 is contacted by a discontinuous second electrode layer, which forms separated sections 35. The sections 35 are within the respective acceptance angle of each of the lenses 36 of the lens array, which are depicted by the shown dotted lines.

Each section 35 of the second electrode layer is formed asymmetrically with an aspect ratio of 2:1. Thus, the resulting beam angle of the output beam is also 2:1. In the present embodiment, each section 35 of the second electrode layer exhibits a length of 1 mm and a width of 0,5 mm. The length 37 between two corresponding edges of each section is 2 mm and the length 38 is 1mm. This specific set up leads to a beam,

which has a beam width of  $20^\circ/10^\circ$  respectively, which is especially advantageous in automotive signalling applications. The set up shown in fig. 3 further exhibits a fill factor of  $1/8$ , which is very energy efficient. When forming the sections 35 asymmetrical as explained above, standard rotation-symmetric lenses can advantageously be used.

## CLAIMS:

1. A lighting device with
  - at least one continuous OLED layer (4) with opposed first and second surfaces,
  - a first electrode layer (5), which electrically contacts to said first surface of the OLED layer (4),
  - a second electrode layer (6), which electrically contacts to said second surface of the OLED layer (4) and
  - a plurality of optical collimating means spaced from the OLED layer (4) by at least said second electrode layer (6), each defining an acceptance angle, wherein
  - the second electrode layer (6) is only in electrical contact with the OLED layer (4) within spaced sections (6a), arranged within the acceptance angles of the collimating means.
2. A lighting device according to claim 1, where the aspect ratio of the sections (6a) is asymmetrical.
3. A lighting device according to any of the preceding claims, wherein the OLED layer (4) and the optical collimating means are separated from each other in a direction, perpendicular to the surface of the OLED.
4. A lighting device according to any of the preceding claims, wherein the optical collimating means are formed by a plurality of lenses.
5. A lighting device according to any of the preceding claims, wherein the

optical collimating means comprise a polymer foil.

6.           A lighting device according to any of the preceding claims, wherein the second electrode layer (6) is continuous over at least a plurality of sections (6a) and  
5           electrically isolated from the OLED layer (4) by an isolating layer (9) in between the sections (6a).
7.           A lighting device according to any of the claims 1-5, wherein the second electrode layer (6) is discontinuous in between the sections (6a).
- 10
8.           A lighting device according to any of the preceding claims, wherein the collimating means exhibit essentially rotation-symmetric optical collimation properties.

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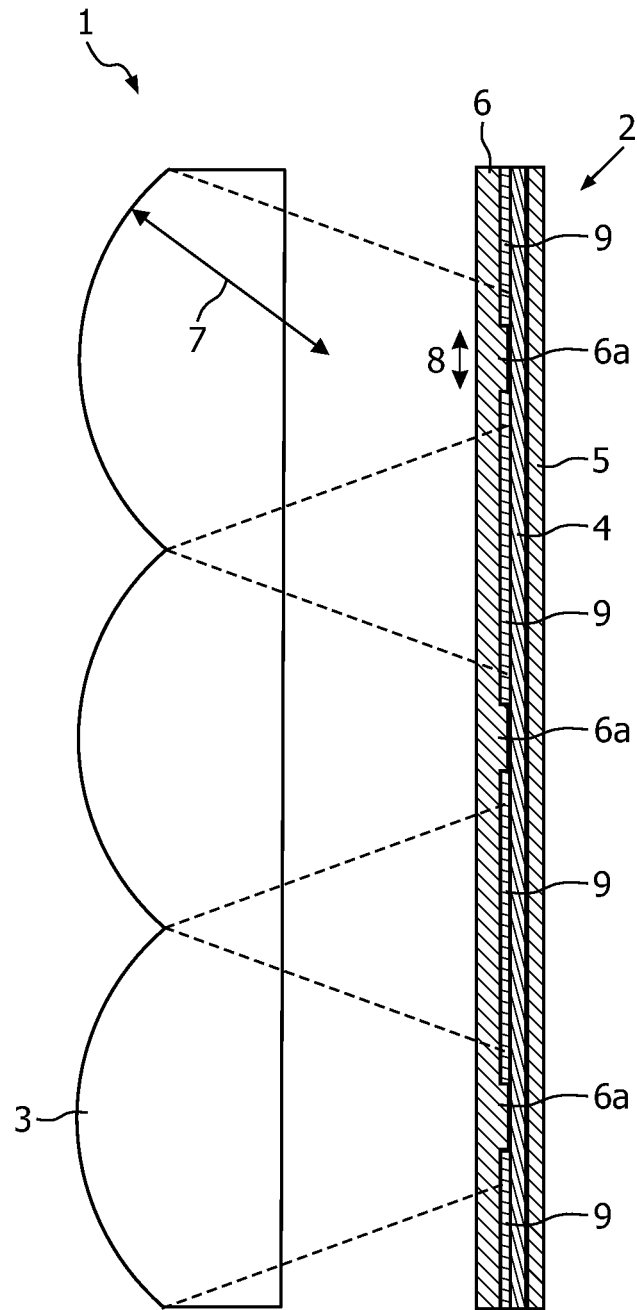


FIG. 1

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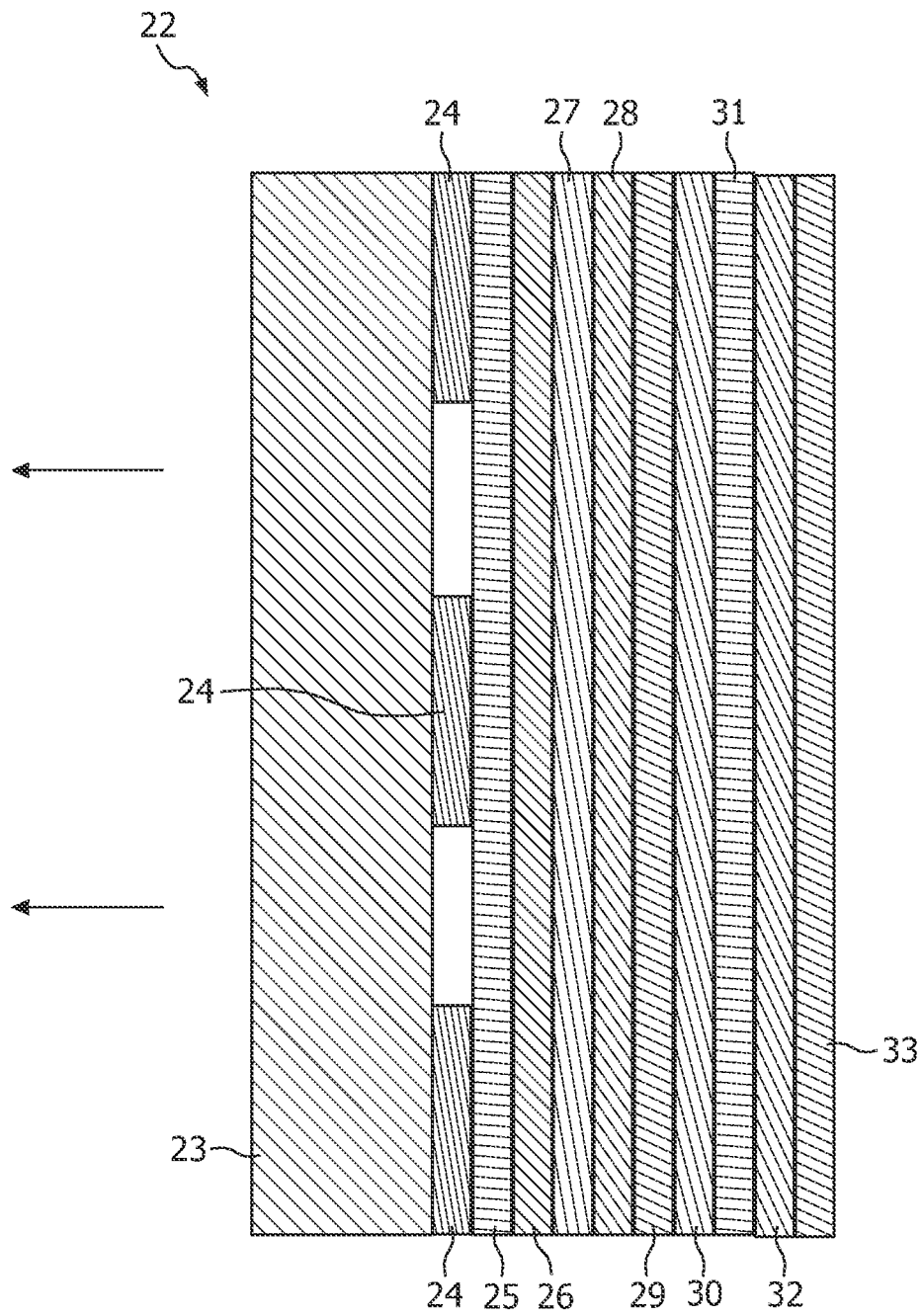


FIG. 2

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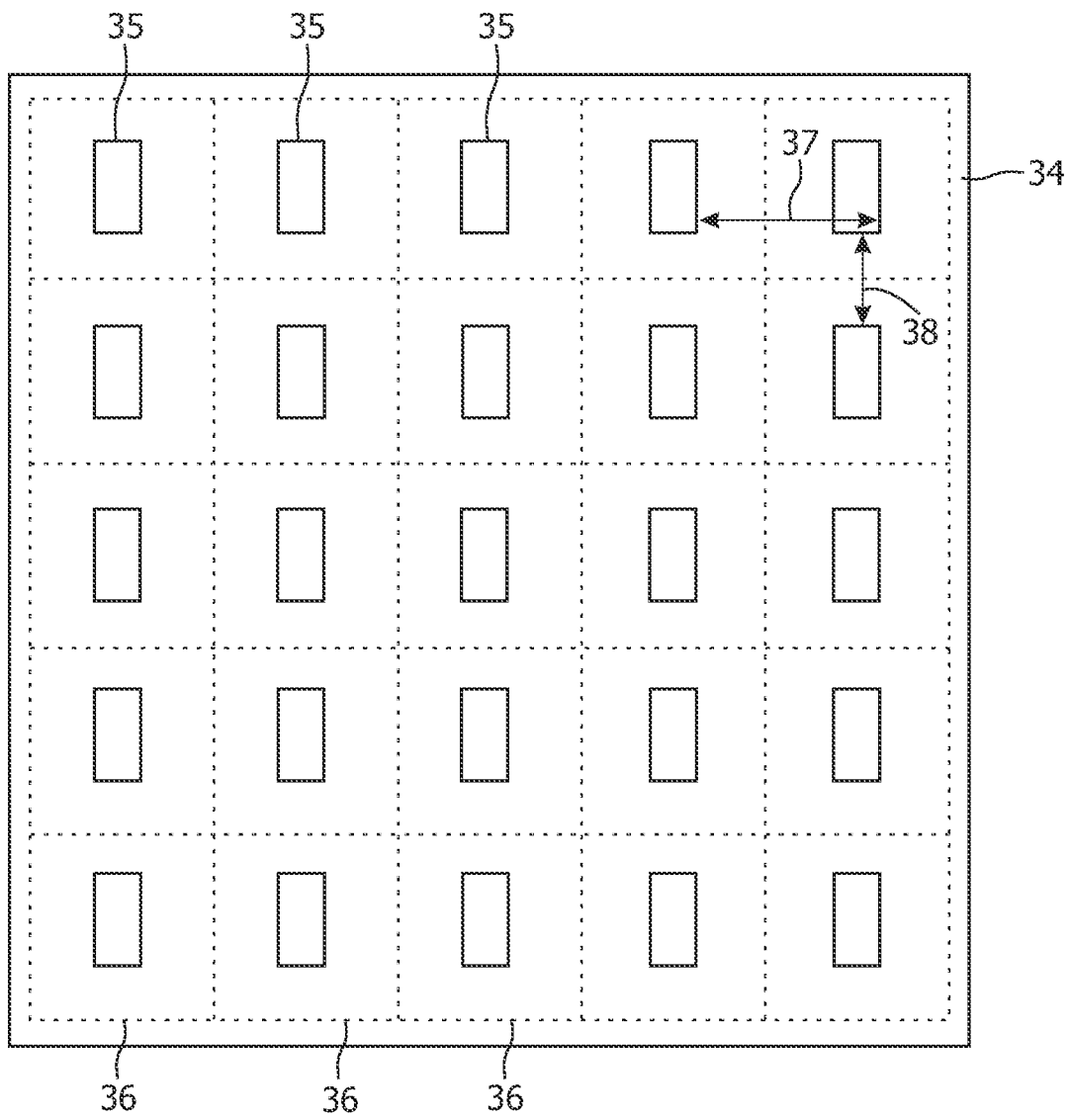


FIG. 3