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(54) **AN ANTIFOULING LIGHT OUTPUT SYSTEM**

(57) An anti-fouling light output system is for mounting over a surface to be protected. A lighting panel (20) has a first surface (51)and an opposite second surface (52), wherein a waveguide is formed between the first and second surfaces. A light source (40) delivers light into the waveguide, and it is, or is converted into, anti-fouling light. The first surface of the panel is for application to the surface to be protected and the second surface is for facing outwardly from the surface to be protected. This second surface comprises a ribbed area (80, 90, 92) having ribs (82) for reducing drag, which ribs are transparent to the anti-fouling light. This arrangement thus combines two measures for drag reduction; a ribbed surface and delivery of anti-biofouling light through those ribs to prevent the formation of biofouling at the ribs.

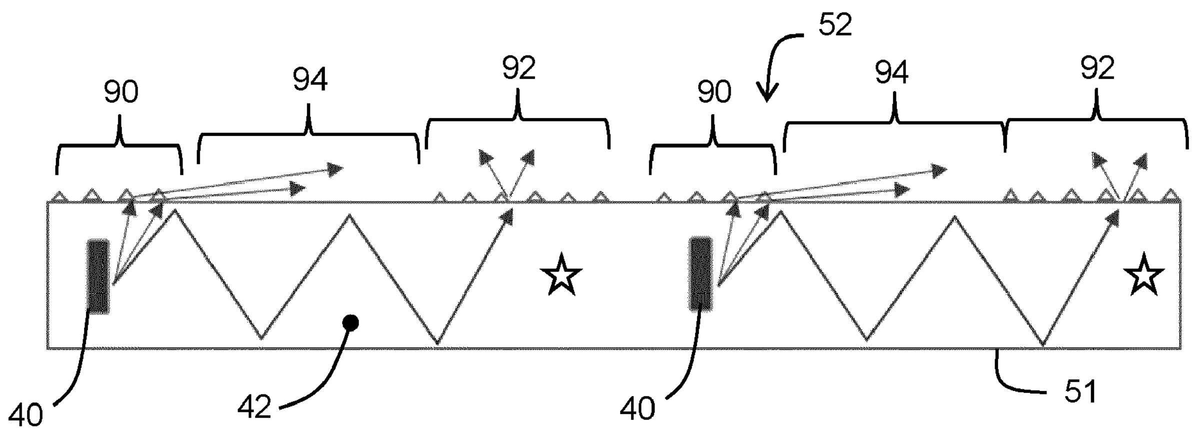

FIG. 6

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Description

FIELD OF THE INVENTION

[0001] The present disclosure relates to systems for preventing biofouling, or commonly referred to as anti-fouling, of surfaces.

BACKGROUND OF THE INVENTION

[0002] Light output systems for application to a surface to prevent biofouling are known. Biofouling or biological fouling is the accumulation of microorganisms, plants, algae, and/or animals on surfaces. The variety among biofouling organisms is highly diverse and extends far beyond attachment of barnacles and seaweeds. According to some estimates, over 1700 species comprising over 4000 organisms are responsible for biofouling. Biofouling is divided into microfouling which includes biofilm formation and bacterial adhesion, and macrofouling which is the attachment of larger organisms. Due to the distinct chemistry and biology that determine what prevents organisms from settling, these organisms are also classified as hard or soft fouling types.

[0003] Calcareous (hard) fouling organisms include barnacles, encrusting bryozoans, mollusks, polychaete and other tube worms, and zebra mussels. Examples of non-calcareous (soft) fouling organisms are seaweed, hydroids, algae and biofilm "slime". Together, these organisms form a fouling community.

[0004] In several circumstances, biofouling creates substantial problems. Machinery stops working, water inlets get clogged, and hulls of ships suffer from increased drag. Hence the topic of anti-fouling, i.e. the process of removing or preventing fouling from forming, is well known.

[0005] In industrial processes, bio-dispersants can be used to control biofouling. In less controlled environments, organisms are killed or repelled with coatings using biocides, thermal treatments or pulses of energy. Nontoxic mechanical strategies that prevent organisms from attaching include choosing a material or coating with a slippery surface, or creation of nanoscale surface topologies similar to the skin of sharks and dolphins which only offer poor anchor points.

[0006] This invention relates in particular to surfaces which are both to be submerged in a fluid (such as water) and also to move through the fluid, such that drag is an issue. By way of example, biofouling on the hull of ships causes a severe increase in drag, and thus increased fuel consumption. It is estimated that an increase of up to 40% in fuel consumption can be attributed to biofouling. As large oil tankers or container transport ships can consume up to €200,000 a day in fuel, substantial savings are possible with an effective method of anti-biofouling.

[0007] WO 2014/188347 discloses a method and system for preventing biofouling in which all of a surface, or a significant amount of a surface, to be kept clean from fouling (e.g. the hull of a ship) is covered with a layer that emits germicidal light, in particular UV radiation. The light is provided as the output from a waveguide, at locations where total internal reflection has been interrupted or where scattering has taken place in the bulk of the material of the waveguide. Thus, it is known to adopt an optical method, in particular using ultra-violet light (UV). It is well-known that most micro-organisms are killed, rendered inactive or unable to reproduce with sufficient UV radiation. This effect is mainly governed by the total dose of UV radiation. A typical dose to kill 90% of a certain micro-organism is 10 mW-hours per square meter.

[0008] Ultraviolet (UV) is that part of electromagnetic light bounded by the lower wavelength extreme of the visible spectrum and the X-ray radiation band. The spectral range of UV radiation is by definition between 100 and 400 nm and is invisible to human eyes. Using the CIE classification the UV spectrum is subdivided into three bands:

UV-A (long-wave) from 315 to 400 nm
UV-B (medium- wave) from 280 to 315 nm
UV-C (short-wave) from 100 to 280 nm

[0009] Various light sources for generating UV are known, such as low-pressure mercury discharge lamps, medium pressure mercury discharge lamps and dielectric barrier discharge lamps.

[0010] A preferred option, for example as proposed in WO 2014/188347, is low cost, lower power UV LEDs. LEDs can generally be included in smaller packages and consume less power than other types of light sources. LEDs can be manufactured to emit (UV) light of various desired wavelengths and their operating parameters, most notably the output power, can be controlled to a high degree. A suitable germicidal dose can easily be achieved with existing UV LEDs.

[0011] Avoiding biofouling is one way to avoid an increase in drag. It is also known that surface micro features, such as ribs, can be used to reduce drag. This is for example disclosed in US 5 133 516.

[0012] However, these two approaches seem incompatible with each other. If an anti-biofouling panel, such as disclosed in WO 2014/188347 is applied over a surface with a detailed surface pattern such as ribs, that pattern will be covered by the panel. However, applying ribs over an anti-biofouling panel will block the light. Thus, both possible stacking orders render one of the two measures inactive. The ribs themselves also promote biofouling which increases drag, so for applications where biofouling is an issue, the benefit of drag reduction by applying ribs is lost by the resulting increase in biofouling.

[0013] There remains a need for a system which can reduce drag by combining the benefits of anti-fouling lighting and surface patterning.

SUMMARY OF THE INVENTION

[0014] The invention is defined by the claims.

[0015] According to examples in accordance with an aspect of the invention, there is provided an anti-fouling light output system for mounting over a surface to be protected, comprising:

a panel having a first surface and an opposite second surface, wherein a waveguide is formed between the first and second surfaces; and
a light source for delivering light into the waveguide, wherein the light is, or is converted into, the anti-fouling light,
wherein the first surface of the panel is for application to the surface to be protected and the second surface is for facing outwardly from the surface to be protected and emitting the anti-fouling light and comprises a ribbed area having ribs for reducing drag, which ribs are at least partially transparent to the anti-fouling light.

[0016] This anti-fouling system comprises a waveguide panel, the outer surface of which has a ribbed area for reducing drag. The ribs are transparent to the UV light so that they deliver light to areas which are particularly prone to biofouling. In this way, the problem of biofouling arising at the ribs, and thereby counteracting the improvement in drag performance caused by the ribs, is addressed.

[0017] The ribs for example have a peak height in the range 20 to 400 μm and a pitch in the range 20 to 150 μm.

[0018] The ribs for example extend in a direction parallel to the intended direction of travel of the surface to be protected through a fluid.

[0019] In a first set of examples, the ribs are for example arranged to out-couple light from the waveguide. The ribs thus become part of the design of the waveguide. The total amount of light that is coupled out of the waveguide is the combination of (i) light scattered in the bulk of the material from air bubbles, etc. and (ii) local disturbances of the surface, such as scratches, paint dots, ribs, etc. Both of these effects cause light to change direction, and then escape from the waveguide, thereby inhibiting the biofouling.

[0020] In one arrangement, the ribbed area is arranged remote from the light source such that the ribs are not present in a region close to the light source at which direct light from the light source is able to escape from the waveguide. The ribs out-couple light from areas where the amount of light out-coupling is low (further from the light source) thus assisting in delivering a more uniform light output across the panel.

[0021] In another arrangement, a first set of ribs of a first type is arranged in a region close to the light source at which direct light from the light source is able to escape from the waveguide, and a second set of ribs of a different, second type, is arranged more remote from the light source than the first set.

[0022] The first set of ribs for example redirect light across the surface so that the light emitted close the light source is spread over the surface, again to create a more uniform illumination over the surface.

[0023] There may then be a space region between the first and second sets which is free of ribs.

[0024] In all of these arrangements in accordance with the first set of examples, the ribbed area (in total) covers an area of the second surface which is at most 70%, for example at most 60% or at most 50% of the total area.

[0025] In a second set of examples, the panel comprises a first layer which defines the waveguide and includes the first surface, and a second layer over the first layer, wherein the second layer has a refractive index, at the wavelength of the light of the light source, lower than the refractive index of the first layer.

[0026] This second layer acts as a barrier between the waveguide and the ribs, so that the ribs do not act as light out-coupling structures. Instead, light only reaches the ribs which has first been scattered in the bulk of the waveguide.

[0027] The second surface may be formed by a third layer, over the second layer, so the ribs are part of an additional layer. Alternatively, the second surface may be formed by the second layer so the ribs are part of the second layer.

[0028] In this second set of examples, the second surface may be fully covered in ribs.

[0029] The waveguide is for example formed of a silicone. This is used to encase and therefore protect the light source as well as providing a light guiding structure so that light is spread over the entire surface of the system.

[0030] The back surface of the waveguide for example has a back reflector, for example of aluminum. Thus, light which is emitted towards a lower (inwardly facing) surface of the light guide and which escapes is reflected back into the light guide so that there is illumination of the upper (outwardly facing) surface.

[0031] The light source for example comprise UV LEDs, such as UV-C LEDs. These provide anti bio-fouling illumination. The light source array is for example UV-C LEDs with wavelength between 230nm and 300nm, for example between 270nm and 280nm.

[0032] The system may further comprise an inductive power receiver comprising one or more power receiving coils for delivering power to the light source. An inductive power transmitter may also be provided comprising one or more primary coils for wireless transmission of power to the one or more power receiving coils, wherein the plurality of inductive power receiving coils are mounted over the inductive power transmitter. A power source is then provided for delivering power to the inductive power transmitter. Thus, the lighting system may be a panel which implements wireless power reception for powering the light source.

[0033] A set of power receiving panels may be coupled to an inductive power transmitter. This provides an effective way to deliver power to the lighting load extending over a large area. In particular, a grid of at least one power delivery transmitter and multiple power receiving panels may be formed, to cover a large area. The inductive power transmission enables the lighting load to be isolated from the power source, in particular so that damage to the load does not result in an electrical short to the power supply. The use of overlapping primary and secondary coils enables a thin overall structure for example if coils formed as PCB tracks are used.

[0034] The invention also provides a marine object comprising an anti-fouling system as defined above. An outer surface of the marine object (i.e. a surface which is exposed to marine water) is the surface over which the inductive power transmitter and inductive power receiver panels are mounted.

[0035] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] For a better understanding of the invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:

Fig. 1 shows an anti-fouling light output system applied to a ship for protecting the surface of the ship in contact with water, i.e. the hull surface;
Fig. 2 shows a cross section (in a horizontal plane) through the inductive power transmitters and lighting panels;
Fig. 3 shows the coil arrangements in more detail;
Fig. 4 shows an example of the structure of the lighting panel;
Fig. 5 shows a first example of a lighting panel with a ribbed area;
Fig. 6 shows a second example of a lighting panel with two ribbed areas;
Fig. 7 shows a third example of a lighting panel with an additional second layer;
Fig. 8 shows fourth example of a lighting panel with ribs embossed into the top surface of the second layer; and
Fig. 9 shows a lighting panel with rows of side-emitting UV LEDs which emit light in a vertically downward direction and with ribs which extend horizontally.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0037] The invention will be described with reference to the Figures.

[0038] It should be understood that the detailed description and specific examples, while indicating exemplary embodiments of the apparatus, systems and methods, are intended for purposes of illustration only and are not intended to limit the scope of the invention. These and other features, aspects, and advantages of the apparatus, systems and methods of the present invention will become better understood from the following description, appended claims, and accompanying drawings. It should be understood that the Figures are merely schematic and are not drawn to scale. It should also be understood that the same reference numerals are used throughout the Figures to indicate the same or similar parts.

[0039] The invention provides an anti-fouling light output system for mounting over a surface to be protected. A lighting panel has a first surface and an opposite second surface, wherein a waveguide is formed between the first and second surfaces. A light source delivers light into the waveguide, which is, or is converted into, anti-fouling light. The first surface of the panel is for application to the surface to be protected and the second surface is for facing outwardly from the surface to be protected. This second surface comprises a ribbed area having ribs for reducing drag, which ribs are transparent to the anti-fouling light. This arrangement thus combines two measures for drag reduction; a ribbed surface and delivery of anti-biofouling light through those ribs to prevent the formation of biofouling at the ribs.

[0040] Fig. 1 shows an anti-fouling light output system, which may be adapted in accordance with the invention, applied to a ship 1, for protecting the surface of the ship in contact with water, i.e. the hull surface.

[0041] The anti-fouling light output system comprises a set of inductive power transmitters 10 mounted over the surface. They take the form of power feeding lines, i.e. strips, which extend vertically against the hull. At the upper ends, the feeding lines connect to a source of electric power (not shown). The inductive power transmitters each comprise one or more sets of primary windings. A set of primary windings (whether there is one or more than one winding) is referred to as a primary coil in this document. Thus, the inductive power transmitter has one or more primary coils.

[0042] A set of lighting panels 20 is also mounted over the surface. The lighting panels 20 are one example of possible inductive power receiving panels. The lighting panels each comprise a light source arrangement and an inductive power receiver with one or more sets of secondary windings for alignment with the primary windings. A set of secondary windings (whether there is one or more than one winding) is referred to as a secondary coil in this document. Thus, the term "coil" generally is used to denote a set of windings forming one side of a transformer. A primary coil is aligned with a secondary coil to form a transformer.

[0043] As will be clear from the description below, there may be multiple coils on each power feeding line, for example one or more coils along the power feeding line at the location of each lighting panel. Each power feeding line supplies power to multiple lighting panels, thus providing a space efficient arrangement. Each lighting panel may also have one secondary coil or multiple secondary coils (e.g. on opposite sides).

[0044] Fig. 2 shows a cross section (in a horizontal plane) through the power feeding lines (the inductive power transmitters 10) and through the lighting panels 20. Each lighting panel may be considered to form an anti-fouling light output system.

[0045] The inductive power transmitters comprise a primary coil 12 and a ferrite sheet 14 between the windings of the primary coil and the metal of the hull 16 of the ship. The surface 18 of the hull is the surface to be protected from fouling. The ferrite sheets prevent Eddy currents in the metal of the ship's hull 16 thereby increasing the efficiency of energy transfer.

[0046] In the example shown, the surface 18 is essentially fully covered by the lighting panels. Thus, the surface 18 is protected by the lighting panels, and it is the exposed surface of the lighting panels which is vulnerable to fouling. Thus, the lighting provided by the lighting panels aims to prevent the formation of fouling organisms on the surface of the lighting panels.

[0047] However, this is still to be understood as forming a system for protecting the hull surface against biofouling (in that without the light output system, the hull surface will suffer from biofouling).

[0048] In the example shown in Fig. 2, the inductive power transmitters 10 are mounted against the hull surface 18 and the lighting panels 20 are mounted over the inductive power transmitters.

[0049] In particular, an edge region 22 of each lighting panel 20 overlaps the feeding lines. The lighting panels 20 each have a secondary coil 24 located in this edge region, and a light source arrangement 26.

[0050] The secondary windings are aligned with the primary windings to provide inductive power transfer. The wirelessly transmitted power is used by the lighting panels 20 to power the light source arrangements 26.

[0051] The primary coils may be formed on or within a printed circuit board of the feeding lines, and the secondary coils may also be formed on or within a printed circuit board of the lighting panel. The light source arrangement may also be formed on a printed circuit board, which may be separate to, or the same as, the printed circuit board of the secondary coils. A shared flexible printed circuit board may for example allow the lighting panels to adapt to the contour of the underlying feeding lines. Instead, there may be separate printed circuit boards in the lighting panel and an electrical connection between them.

[0052] Fig. 3 shows the coil arrangements.

[0053] The example of Fig. 2 has the lighting panels overlapping an associated feeding line at one edge. In Fig. 3, the lighting panels 20 overlap feeding lines 10 at both lateral edges, and each feeding line 10 has pairs of primary coils arranged along its length. One coil of a pair is for powering a lighting panel to one side and the other coil of the pair is for powering a lighting panel to the other side. In this way, each lighting panel is supplied by power from both sides.

[0054] Thus, there may be one coil assembly (i.e. primary coil and secondary coil) per lighting panel (Fig. 2) or two coil assemblies per lighting panel (Fig. 3).

[0055] There may for example be between 2 and 50 lighting panels per feeding line, for example 20 rows of individual panels connected to a feeding line.

[0056] In the example shown, the feeding lines extend in a substantially vertical orientation along the side of the ship. However, any suitable arrangement of feeding lines is possible. The feeding lines may for example cover welding seams and/or other surface irregularities of the ship's hull.

[0057] Fig. 4 shows an example of a known structure of the lighting panel 20, having a plurality of light sources 40 which in this example are side-emitting UV-C LEDs, wherein the light is emitted primarily from a side of the LED, and more or less parallel to the surface. The light sources 40 are encapsulated in a liquid-tight optical medium 42 to guide at least part of the light 44 emitted from the light sources 40 via total internal reflection through the optical medium.

[0058] Optical structures 46 are provided to disrupt the total internal reflection and scatter light, and then guide the scattered light 48 out of the optical medium 42 towards a target for the light, which is an area where a biofouling organism could be present.

[0059] A biofouling organism on the surface 52 will directly receive the scattered light 48 before it enters the water.

[0060] The illumination means that single cell biomechanisms at the surface 52 will stop growing and dividing, and will therefor disappear under influence of the UV-C radiation.

[0061] The optical medium is relatively thin so that the lighting panel may be considered to be a two-dimensional structure. The optical structures 46 to scatter light may be spread in one or more portions of the optical medium material, possibly throughout all of it, and the light output may be generally homogeneous or else localized.

[0062] Internal scattering centers with different structural properties may be combined to provide optical as well as structural characteristics, such as resistance to wear and/or impact. Suitable scatterers comprise opaque objects but largely translucent objects may be used as well, e.g. small air bubbles, glass and/or silica; a requirement is merely that a change in refractive index occurs for the wavelength(s) used. The optical structures may be printed structures, such as of a UV reflective material such as barium nitride or aluminum oxide.

[0063] The principle of light guiding and spreading light over a surface is well-known and widely applied in various fields. Here, the principle is applied to UV radiation for the purpose of anti-fouling.

[0064] To maintain the conditions for total internal reflection, the index of refraction of the light guiding material should be higher than that of the surrounding medium. However, the use of (partly) reflective coatings on the light guide and/or the use of the reflective properties of the protected surface, e.g. the hull of a ship, itself can also be used to establish the conditions for guiding the light through the optical medium.

[0065] As most materials have a (very) limited transmittance for UV radiation, care has to be taken in the design of the optical medium. As a result, a relatively fine pitch of low power LEDs can be chosen, to minimize the distance light has to travel through the optical medium.

[0066] In one example, the optical medium 42 comprises a silicone, and one which is designed to have good UV-C transparency.

[0067] To the extent described above with reference to Figs. 1 to 4, the anti-fouling light output system is known.

[0068] The invention provides a modification to the anti-fouling light output system described above in which a first surface of the panel is smooth and is for application to the surface to be protected and the second surface is for facing outwardly from the surface to be protected and comprises a ribbed area having ribs for reducing drag. The ribs are transparent to the UV light of the UV light source.

[0069] Fig. 5 shows a first example of a lighting panel, having a first surface 51 for application to the surface to be protected and an opposite second surface 52 (i.e. the outer surface 52 described with reference to Fig. 4). A waveguide is formed between the first and second surfaces 51, 52. A UV light source delivers light into the waveguide. The light source is encapsulated in the waveguide as shown.

[0070] The outer surface 52 has a ribbed area 80 having ribs 82 for reducing drag. The ribs 82 are transparent to the UV light so that they deliver light to areas which are particularly prone to biofouling. In this way, the problem of biofouling arising at the ribs, and thereby counteracting the improvement in drag performance caused by the ribs, is addressed.

[0071] The ribs for example have a peak height in the range 20 to 400 μm and a pitch in the range 20 to 150 μm.

[0072] In one example, the ribs example extend in a direction parallel to the intended direction of travel of the surface to be protected through a fluid. However, the ribs may be aligned differently. In particular: the primary function of the ribs is to form a superhydrophobic surface, which makes it easier for the waves and currents to detach from the hull.

[0073] The use of ribs for reducing drag has been studied extensively recently. Examples of papers include "A Numerical Study of the Effects of Superhydrophobic Surfaces on Skin-Friction Drag" of Hyunwook Park, UCLA Electronic Theses and Dissertations (https://escholarship.org/uc/item/4vz7m8hb).

[0074] In a first set of examples, the ribs are for example arranged to out-couple light from the waveguide. The ribs thus become part of the design of the waveguide, in particular part of the overall design how light is out-coupled from the waveguide.

[0075] Fig. 5 shows a first arrangement, in which the ribbed area 80 is arranged remote from the UV light source 40 such that the ribs are not present in a region close to the UV light source at which direct light from the UV light source is able to escape from the waveguide. This close region is a region where the angle between the light emitted and the second surface 52 is less than the critical angle for total internal reflection. The ribs out-couple light from areas where the amount of light out-coupling is low (further from the light source) thus assisting in delivering a more uniform light output across the panel. The ribs are everywhere over the waveguide apart from close the light sources.

[0076] By way of example, the area 80 has a length in the range 2 cm to 4 cm and also spaced from the LED 40 by a spacing in the range 2cm to 4cm.

[0077] Fig. 6 shows a second arrangement with a first set 90 of ribs of a first type arranged in a region close to the UV light source at which direct light from the UV light source is able to escape from the waveguide, and a second set 92 of ribs of a different, second type, is arranged more remote from the UV light source than the first set.

[0078] By way of example, the area 90 has a length in the range 0.5 cm to 2 cm and the spacing 94 from the LED 40 is in the range 2cm to 4cm.

[0079] The first set 90 of ribs for example redirect light across the surface so that the light emitted close the light source is spread over the surface, again to create a more uniform illumination over the surface. There is a lot of light out-coupled at this region because it does not meet the total internal reflection angle (as explained above), so this arrangement provides processing of this light. The ribs of the first set for example have a shape and slant angles to redirect light toward a direction parallel to the second surface 52.

[0080] In this design there is a space region 94 between the first and second sets 90, 92 which is free of ribs.

[0081] For the examples of Figs. 5 and 6, the total ribbed area (the sum of sets 90 and 92) covers an area of the second surface 52 which is at most 70%, for example at most 60% for example at most 50% of the total area.

[0082] Fig. 7 shows a first example of a second set of examples, in which the panel comprises a first layer 42 which defines the waveguide and includes the first surface 51, and a second layer 100 over the first layer, wherein the second layer 100 has a refractive index, at the wavelength of the light of the UV light source, lower than the refractive index of the first layer 42.

[0083] The second layer 100 acts as a barrier between the waveguide and the ribs, so that the ribs do not act as light out-coupling structures. Instead, light only reaches the ribs which has been out-coupled by scattering centers of the waveguide design. In this way, the light out-coupling function and the drag reduction function may be designed and optimized independently.

[0084] By way of example, the second layer 100 comprises fluorinated ethylene propylene (FEP) which has a refractive index of 1.34 compared to the silicon refractive index which is in the range 1.40 to 1.50.

[0085] Fig. 7 shows an example in which ribs 102 are formed over the second layer 100 and thus are part of an additional third layer. The ribs may cover the full area of the second surface 52.

[0086] Fig. 8 shows an alternative example in which the ribs 102 are embossed into the top surface of the second layer 100. The ribs may again cover the full area of the second surface 52.

[0087] Generally, the lighting panels for example have a PCB thickness of 0.8mm, and the total thickness with the silicone of below 5mm, for example in the range 1mm to 4mm.

[0088] The lighting panels for example have a length (along the horizontal row direction) in the range 1m to 5m and a height (along the vertical column direction) in the range 50cm to 150cm. For example a small panel dimension may be 600mm x 1200mm and a large panel dimension may be 1m x 4m. An example area to be covered, e.g. one side of a ship hull, may be of the order of 100m length by 10m height.

[0089] As mentioned above, the ribs extend in the direction of travel of the vessel. The illumination direction of the UV light source is preferably perpendicular to the elongate axes of the ribs, as schematically shown in Figs. 5 to 8. Fig. 9 shows a lighting panel 20 with rows of side-emitting UV LEDs 40 which emit light in a vertically downward direction, whereas the ribs 82 extend horizontally.

[0090] This is just one example, and the ribs may be rotated by 90 degrees, or indeed they may be arranged with any orientation. Indeed, any known rib design and dimensions may be used which has been found suitable for drag reduction.

[0091] The anti-fouling implementation of the invention is of interest for marine objects although not limited to objects for use in seawater, but also in any type of water that is known to contain biofouling organisms. Examples of marine objects include ships and other vessels. The invention is of particular interest for objects which are propelled to move through water.

[0092] In preferred examples, the light sources are UV LEDs as explained above. A grid of UV LEDs may be encapsulated in a liquid-tight encapsulation, of which silicone is only one example. The UV LEDs may be electrically connected in a series and/or parallel arrangement. The UV LEDs are for example packaged surface mount LEDs, in which case they already may include an optical element to distribute the light emitted from the LED package across a wide emission angle. In other embodiments, the UV LEDs may be LED dies, typically not comprising optical elements but being significantly thinner than packaged LEDs. As an example, LED dies could be picked and placed onto a surface of the optical medium.

[0093] The silicone material can be selected to provide optical transmission for UV radiation with little loss compared to other materials. This is in particular the case for shorter wavelength light, e.g. UV radiation with wavelengths below 300 nm. A particularly efficient group of silicone materials is, or at least comprises, so-called methyl silicones, according to the general chemical formula $CH_3[Si(CH_3)_2O]_nSi(CH_3)_3$, with "n" indicating any suitable integral.

[0094] Silicone materials are also flexible and resilient so that they are robust, durable and capable of withstanding compression such as due to bumps, collisions etc. of objects against the surface, e.g. bumping of a ship against a quay. Furthermore, deformation due to temperature fluctuation, pounding by waves, flexion of the ship over swell etc. may be accommodated.

[0095] A wavelength conversion material may be comprised in the optical medium and at least part of the anti-fouling light may be generated by photo-exciting the wavelength conversion material with light having a first wavelength causing the wavelength conversion material to emit the anti-fouling light at another wavelength. The wavelength conversion material may be provided as an up-conversion phosphor, quantum dots, nonlinear media such as one or more photonic crystal fibers etc. Since absorption and/or scattering losses in the optical medium for light of different, mostly longer, wavelengths than UV radiation tend to be less pronounced in the optical media, it may be more energy-efficient to generate non-UV radiation and transmit that through the optical medium and to generate UV anti-fouling light at or near the desired location of use thereof (i.e. emission form the surface into the liquid environment).

[0096] The wavelength conversion material explained above may be part of the rib structure (and material). When the ribs are placed at a distance from the light source as explained above, the transmission distance is is more easily covered with a higher wavelength, such as visible wavelengths. The light source may for example comprise both a visible light LED, and a UV-C LED. From a construction point of view, it may be more beneficial to mix the up-conversion material with the second layer 100 described above, rather than with the bulk of the waveguide material, since this could cause too much light to be converted too soon.

[0097] One example described above makes use of inherently side-emitting LEDs and optical scattering sites. However, light spreading arrangements may be used to create the sideways light. For example, a cone may be arranged in the optical medium and positioned opposite the light source, where the opposing cone has a surface area with a 45° angle perpendicular to the protected surface for reflecting light emitted by the light source perpendicular to said surface in a direction substantially parallel to said surface.

[0098] The LEDs may be DC driven. However, a pair of back to back parallel LEDs may be driven by an AC drive signal.

[0099] Although UV radiation is the preferred solution, other wavelengths are envisaged as well. Non-UV radiation (e.g. visible light) is also effective against biofouling. Typical micro- organisms are less sensitive to non-UV radiation than to UV radiation, but a much higher dose can be generated in the visible spectrum per unit input power to the light sources.

[0100] The light output system may be designed by ray tracing software. Various parameters of the design of the waveguide and the ribs may be adjusted, and the resulting illumination profile may then be simulated. An optimization of the adjustable parameters may then be performed to achieve desired optical characteristics, such as uniformity of intensity over area, or a desired intensity at the rib locations relative to the remainder of the surface, while maintaining the desired properties of the ribs for drag reduction. Commercially available ray tracing software for optical design is abundantly available, for instance software packages like LightTools, ASAP, Zemax, Code-V, 3DsMax, Maxwell and V-Ray.

[0101] Parameters of the optical design which can be varied within certain ranges for example include aspects like the exact thickness of the waveguide, the position of the LEDs inside the waveguide, such as the distance from the top or bottom surface, the distance between individual LEDs (the pitch), the angular light distribution from the LED, the distance from the LED to the rib structure, the area covered by ribs (for example as a percentage of the total area), etc.

[0102] The optimum design could be defined as the design that has the most uniform light output as indicated above, or the design that needs the least amount of power to reach at least a certain light level all over the surface, or the design that needs the least amount of LEDs to achieve either of those goals.

[0103] The raytracing enables various designs to be evaluated so that a best (or preferred) design can be found.

[0104] In the examples above, the lighting panel overlaps the feeding lines. This provides galvanic isolation between the power supply and the structure which is exposed to the water. The lighting panel also protects the underlying feeding line. Instead, the feeding lines may be provided over the lighting panels. A separate electrical isolation may be provided (e.g. at the top of the feeding lines). The surface of the feeding lines will then be susceptible to biofouling, so it should then be ensured that light reaches the surface of the feeding lines, either by transmission through the feeding lines or by reflection or waveguide transmission within the lighting panels. Thus, the inductive power transmitter and the lighting panel are both for mounting over the surface, but in either order.

[0105] Variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. If the term "adapted to" is used in the claims or description, it is noted the term "adapted to" is intended to be equivalent to the term "configured to". Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. An anti-fouling light output system for mounting over a surface to be protected, comprising:

    a panel (20) having a first surface (51) and an opposite second surface (52), wherein a waveguide is formed between the first and second surfaces; and
    a light source (40) for delivering light into the waveguide, wherein the light is, or is converted into, the anti-fouling light,
    wherein the first surface of the panel is for application to the surface to be protected and the second surface is for facing outwardly from the surface to be protected and emitting the anti-fouling light and comprises a ribbed area (80, 90, 92) having ribs (82) for reducing drag, which ribs are at least partially transparent to the anti-fouling light.

2. The system as claimed in claim 1, wherein the ribs have a peak height in the range 20 to 400 μm and a pitch in the range 20 to 150 μm.

3. The system as claimed in claim 1 or 2, wherein the ribs extend in a direction parallel to the intended direction of travel of the surface to be protected through a fluid.

4. The system as claimed in any preceding claim, wherein the ribs (82) are arranged to out-couple light from the waveguide.

5. The system as claimed in claim 4, wherein the ribbed area (80) is arranged remote from the light source such that the ribs are not present in a region close to the light source at which direct light from the light source is able to escape from the waveguide.

6. The system as claimed in claim 4, wherein a first set (90) of ribs of a first type is arranged in a region relative to the light source at which direct light from the light source is able to escape from the waveguide, and a second set (92) of ribs of a different, second type, is arranged more remote from the light source than the first set.

7. The system as claimed in claim 6, wherein there is a space region (94) between the first and second sets which is free of ribs.

8. The system as claimed in any one of claims 4 to 7, wherein the ribbed area covers an area of the second surface which is at most 50% of the total area.

9. The system as claimed in any one of claims 1 to 3, wherein the panel comprises a first layer (42) which defines the waveguide and includes the first surface (51), and a second layer (100) over the first layer, wherein the second layer (100) has a refractive index, at the wavelength of the light of the light source, lower than the refractive index of the first layer (42).

10. The system as claimed in claim 9, wherein:

the second surface (52) is formed by a third layer, over the second layer; or
the second surface (52) is formed by the second layer (100).

11. The system as claimed in claim 9 or 10, wherein the second surface (52) is fully covered in ribs.

12. The system as claimed in any preceding claim, wherein the light source comprises an array of UV LEDs (40).

13. The system as claimed in any preceding claim, further comprising an inductive power receiver (24) comprising one or more power receiving coils for delivering power to the light source.

14. The system as claimed in claim 13, further comprising an inductive power transmitter comprising one or more primary coils for wireless transmission of power to the one or more power receiving coils, wherein the plurality of inductive power receiving coils are mounted over the inductive power transmitter.

15. A marine object comprising a surface to be exposed to marine water and the anti-fouling light output system as claimed in any preceding claim provided over the surface to be exposed to marine water.

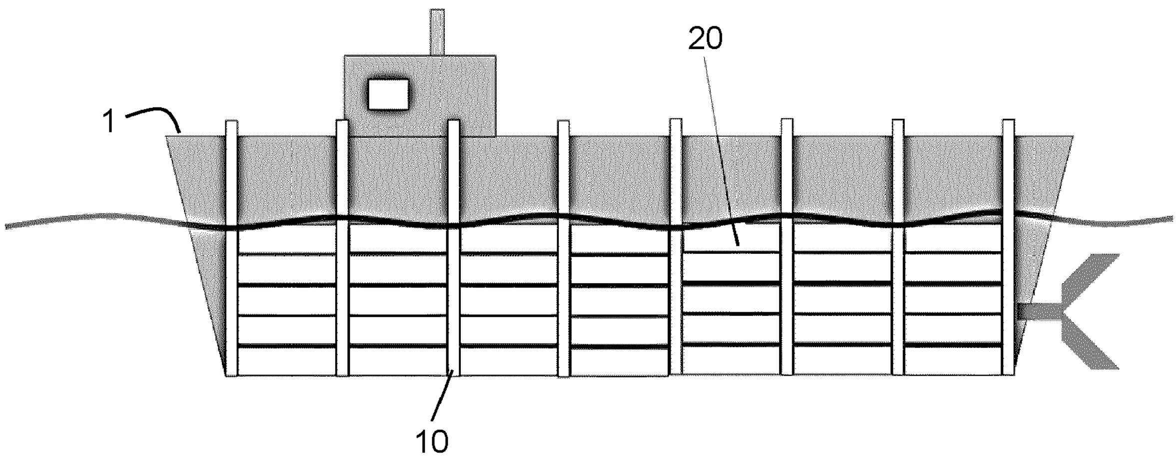

FIG. 1

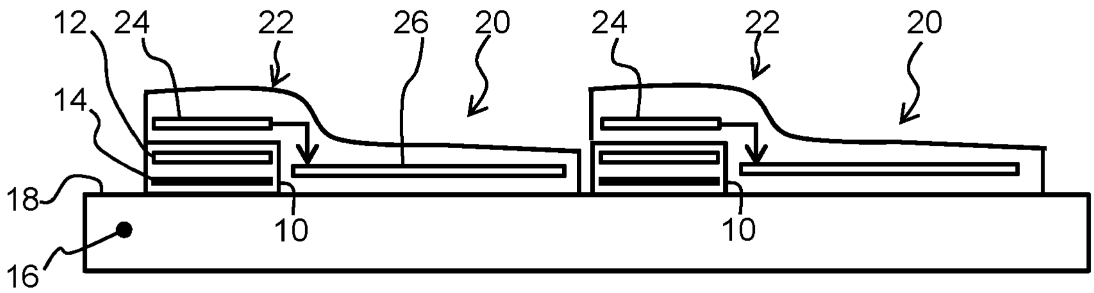

FIG. 2

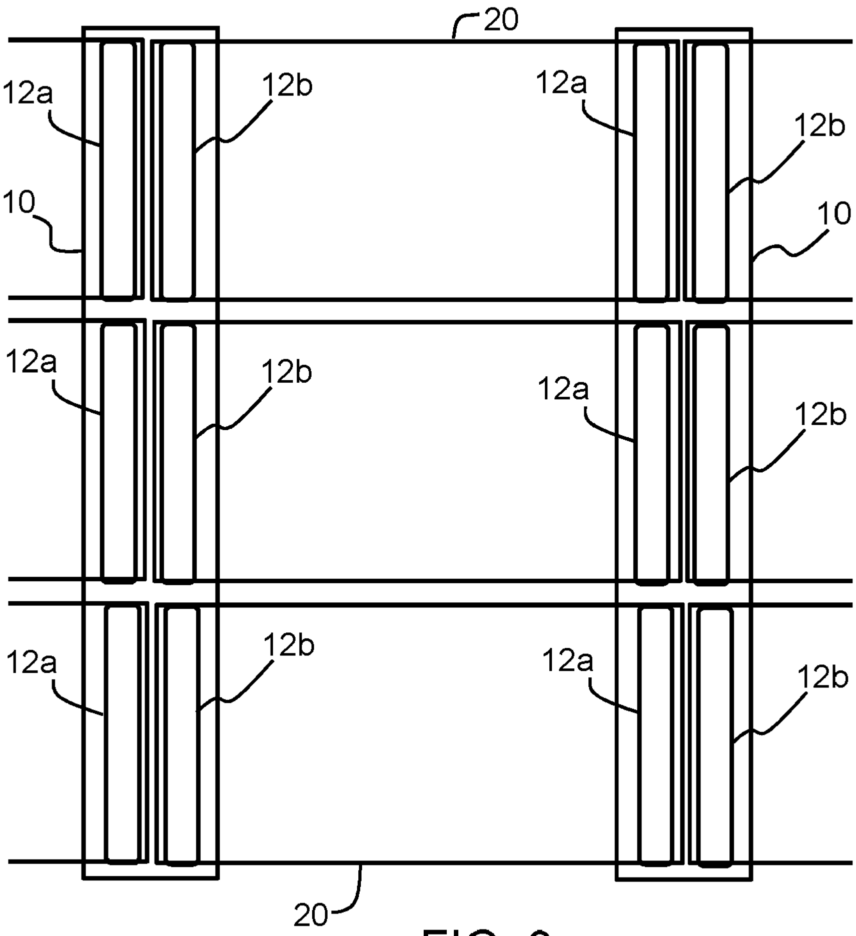
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FIG. 3

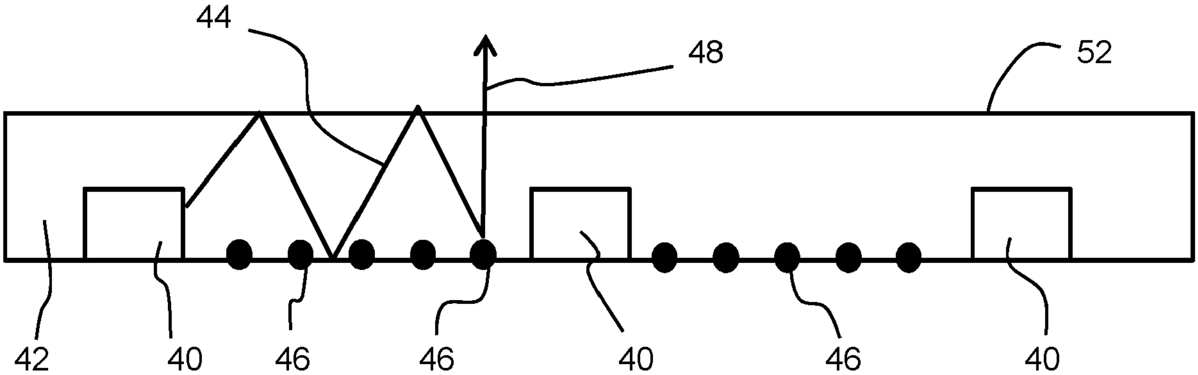
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FIG. 4

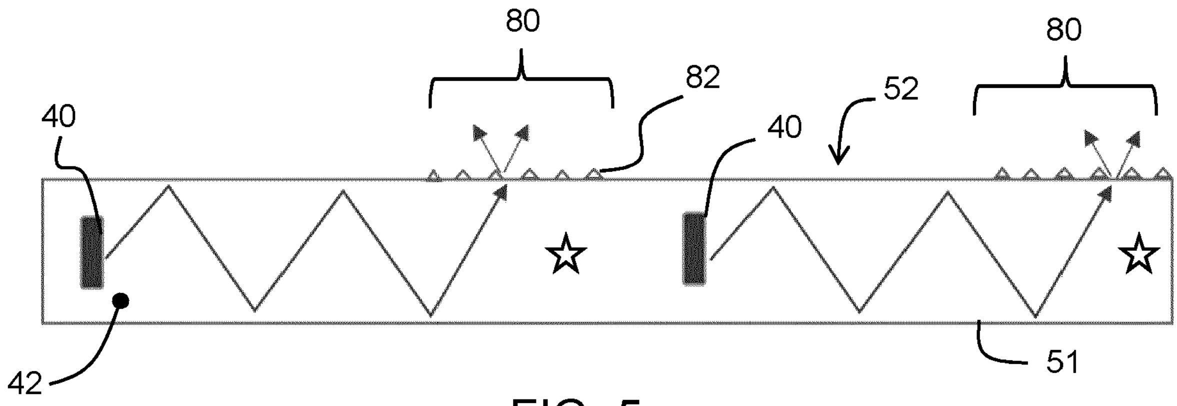

FIG. 5

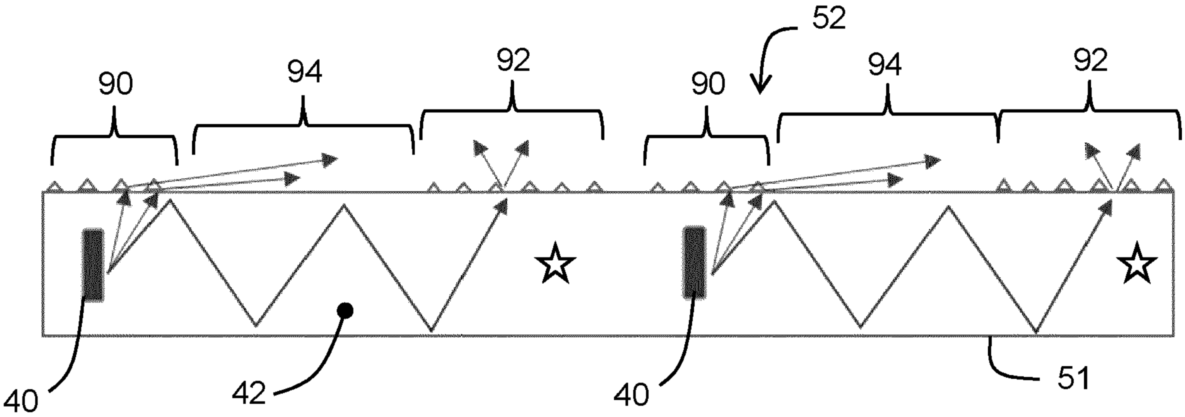

FIG. 6

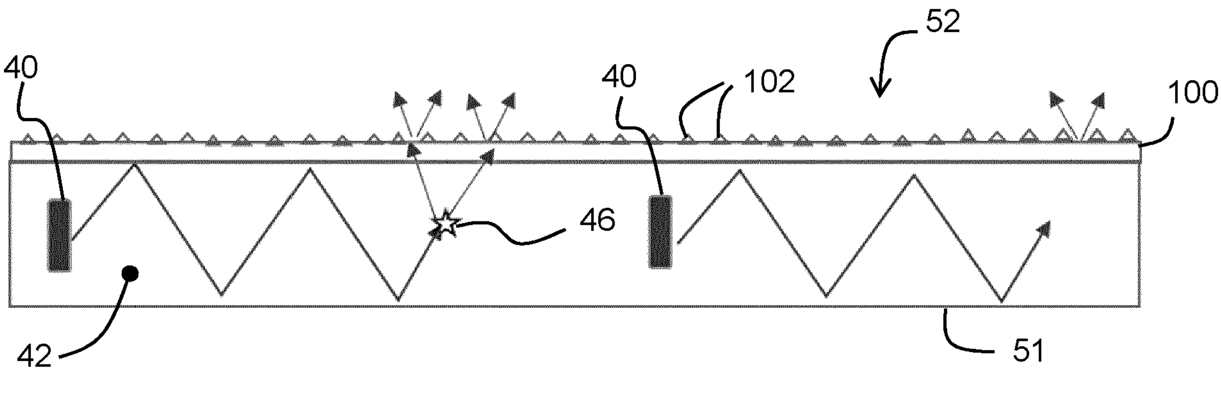

FIG. 7

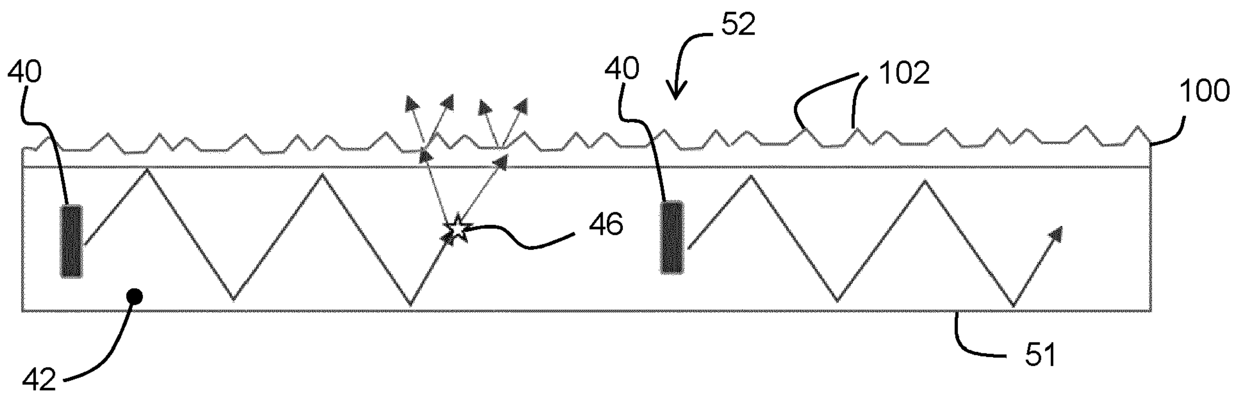

FIG. 8

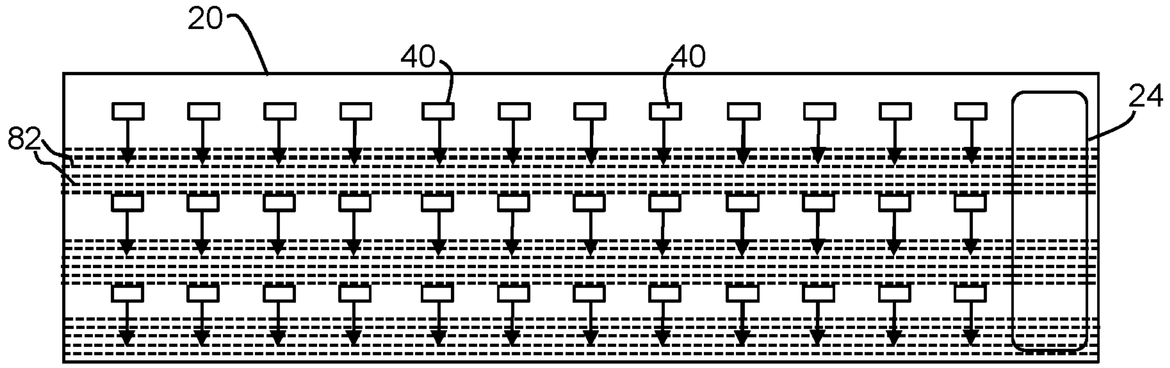

FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 7979

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Y,D	WO 2014/188347 A1 (KONINKLIJKE PHILIPS NV [NL]) 27 November 2014 (2014-11-27) * abstract * * page 1, line 2 - line 4 * * page 2, line 1 - line 9 * * page 5, line 10 - line 17 * * page 12, line 21 - line 32 * * page 14, line 20 - page 15, line 7 * * claims * * figures * -----	1-15	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	8 September 2020	van der Zee, Willem

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 7979

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

1

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