



(51) International Patent Classification:

Not classified

(21) International Application Number:

PCT/EP2017/075147

(22) International Filing Date:

04 October 2017 (04.10.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

16192856.9 07 October 2016 (07.10.2016) EP

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

(84) Designated States (unless otherwise indicated, for every  
kind of regional protection available): ARIPO (BW, GH,  
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,  
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,  
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,  
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,

MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,  
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,  
KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

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

Published:

— without international search report and to be republished  
upon receipt of that report (Rule 48.2(g))

(54) Title: VITAMIN D LIGHTING SYSTEM

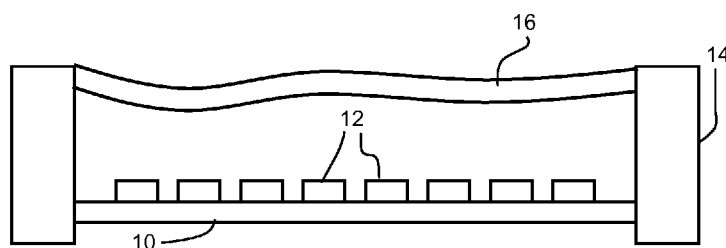


FIG. 1

(57) Abstract: A lighting system comprises a housing, an arrangement of UV-B LEDs in the housing and a fabric output screen which provides a UV-B exit surface. This provides UV-B light for an indoor application in order to replicate the health benefits of natural sunlight.



Vitamin D lighting system

## FIELD OF THE INVENTION

This invention relates to lighting systems, in particular for enabling the synthesis in the human body of vitamin D.

5

## BACKGROUND OF THE INVENTION

People spend approximately 90% of their time indoors, a substantial amount of this at work, in an office.

10 However, natural sunlight is essential for the human body, for example for vitamin D production. It would therefore be desirable to have times during the working day when exposed to natural sunlight. This exposure for example would help the prevention of osteomalacia in adults. Studies have found that 90% of the population worldwide is below sufficient levels of Vitamin D, because of too limited exposure to Sunlight (UV), especially in winter time. A correlation between low vitamin D levels and the incidence of a large  
15 number of health issues has been identified, for example mood, energy, muscle weakness, cardiovascular disease, multiple sclerosis, diabetes, obesity, depression, Alzheimer's, cancers, etc.

20 More and more people want a better work-life balance, and would therefore appreciate exposure to more healthy lighting during the working day. In addition, increasing numbers of people take vitamin D supplements for the prevention of osteomalacia, because of the problem that artificial lighting does not enable sufficient synthesis of vitamin D.

25 However, it is not easy to provide natural sunlight in an office environment. There is therefore a need for a lighting system which is able to replicate the benefits of natural sunlight, but which can be used in an indoor environment, such as an office environment.

## SUMMARY OF THE INVENTION

The invention is defined by the claims.

According to examples in accordance with an aspect of the invention, there is provided a lighting system, comprising:

- a housing;
- an arrangement of UV-B LEDs in the housing; and
- 5 a fabric output screen which provides a UV-B exit surface.

This system provides UV-B light for indoor lighting applications, such as for part of an office lighting system. The UV-B lighting may be provided in combination with general visible lighting to provide a stimulation of the health effects as well as visual illumination, preferably the system may provide the appearance of natural daylight.

10 The fabric output screen is at least partially transparent to UV-B light to allow the UV-B light to enter the indoor space. Fabric is not a commonly used material for UV transmission, normally material such as quartz, sapphire, ceramics or certain silicones are chosen but these have limitations when a large panel UV emitting light is desired. The fabric screen for example has a level of transparency which depends on the way the fabric is woven.

15 This transparency is commonly expressed as a denier (D) measurement. Denier is a unit of measurement for the linear mass density of fibers and is the mass in grams of 9000m of the fiber in question. Denier is used to determine the diameter of the fibers in the fabric. The denier is based on a natural reference, that of a single strand of silk. A single strand of silk 9000m long weighs about 1 gram (g) and therefore is 1 denier. The higher the denier number  
20 the greater the diameter of the yarn. The linear density of yarn used in the manufacturing process also determines the perceived visual opacity of the article in the following, commonly used categories:

- ultra sheer; less than 10 denier,
- sheer; 10 to 30 denier,
- 25 • semi-opaque; 30 to 40 denier,
- opaque; 40 to 70 denier, and
- thick opaque; 70 denier or higher.

For example, the fibers in a 40- denier (40D) nylon fabric have a diameter over 6.5 times  
30 greater than the diameter of the silk strand and almost 1.5 times the diameter of fibers in a 20 denier (20D) nylon fabric.

The fabric output screen is preferably at least partially opaque to visible light, giving a translucency with respect to eye visibility. The fabric has a low UV absorption coefficient because it exhibits no fluorescence or phosphorescence. This means the

arrangement of UV-B LEDs is not visible and the visual appearance of the system is simply an unlit fabric screen, for example forming a panel in a modular ceiling installation. The fabric may have a pattern or visual color to match the general décor of the indoor space in which it is mounted.

5                   The housing for example comprises a base which carries the UV-B LEDs and a side wall around the base, wherein the side wall comprises a UV reflector. This improves the output efficiency of the system.

                  The side wall for example comprises a polymer having embedded boron nitride particles. This reflector design can be made highly reflective to UV-B light. The  
10                  reflectivity of the side walls is for example higher than 95% to the UV-B light.

                  The side wall for example comprises a UV-resistant silicone polymer composite with boron nitride, or a boron nitride fluoropolymer composite.

                  The fabric preferably comprises ultra-high-molecular-weight polyethylene fiber (UHMWPE), for example DSM Dyneema (trade mark). This material is highly  
15                  transmissive to UV-B light. For purposes of comparison, so-called “tan-thru” fabrics (generally based on Lycra<sup>®</sup>) have a UV-B transparency of between 3-20%. These materials generally have a known disadvantage of having to be worn close to the skin otherwise they can appear partially see-through, especially if the wearer is between the viewer and the sun. It is also known that if such materials are held up to the light that they appear see through and  
20                  only gain their perceived opacity when worn close to the skin. This makes such materials unsuitable for masking a lighting system, particularly if the material is used as a light exit window for a lighting system having an internal volume, for example, a mixing box.

                  The fibers in the DSM Dyneema for example, have a twine diameter of 3.3mm  
25                  and weight of 5g/m. The fabric is woven in such way as to provide a minimum linear mass density for example of 40 to 200 denier. This means that the LEDs and components on the light engine are not visible to the human eye.

                  The fabric output screen for example has an area of more than 1500cm<sup>2</sup> (e.g. 60cm x 60cm).

30                  The use of a fabric output screen enables a large size panel to be formed with low weight and low cost. These panels may be used as part of a modular ceiling and remain flush to the ceiling, or they may be freestanding or mounted on a wall or to a ceiling.

The UV-B Narrow Band (NB) LEDs for example have a wavelength of 280nm to 315nm which can be easily fine-tuned to an optimal wavelength for making vitamin D in the human body.

Each UV-B LED for example has an output power of 400 $\mu$ W to 800 $\mu$ W. The  
5 total number of UV-B LEDs can be for example in the range 10 to 40 in the panel.

The invention also provides a lighting installation comprising:  
one or more lighting systems as defined above; and  
one or more visible light luminaires.

The combination of visible and UV-B lighting provides the visual and health  
10 benefits corresponding to natural daylight.

The lighting installation for example comprises an office lighting installation.

The lighting systems may each comprise a ceiling panel and the luminaires  
may each comprise a ceiling panel. Alternatively, the lighting systems may comprise a  
freestanding divider for offices or they may be fitted to a wall or ceiling. This provides a  
15 modular system. The ceiling panel embodiment may be preferable as it remains particularly  
unobtrusive within an office space.

## BRIEF DESCRIPTION OF THE DRAWINGS

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

Fig. 1 shows a UV-lighting system; and

Fig. 2 shows an office space with a ceiling having visible lighting and UV-B  
lighting.

## 25 DETAILED DESCRIPTION OF THE EMBODIMENTS

The invention provides a lighting system, comprising a housing, an  
arrangement of UV-B LEDs in the housing and a fabric output screen which provides a UV-  
B exit surface. This provides UV-B light for an indoor application in order to replicate the  
health benefits of natural sunlight.

30 Figure 1 shows a UV-lighting system.

The system comprises a carrier 10 on which an arrangement of UV-B LEDs  
12 is provided. The carrier 10 for example comprises a printed circuit board (PCB), and the  
UV-B LED are surface mount packages for mounting on the PCB.

A side wall 14 forms a housing together with the carrier 10 and the UV-B LEDs 12 provide UV light outwardly, normally away from the carrier 10. The housing may be any desired shape, such as rectangular, square or circular. The housing has a low profile so that it may be integrated into a ceiling structure for example. Alternatively, it may for a light fitting to be suspended below a ceiling.

The housing is closed opposite the carrier 10 by a fabric sheet 16.

The fabric sheet 16 can be produced at low cost, low weight and with large area. For example the overall system may have a size of around 45cm x 45cm or 60cm x 60cm. In this way it may form a panel of a modular lighting system. Generally, the size is more than 1500cm<sup>2</sup>, for example more than 2000cm<sup>2</sup> for example more than 3000cm<sup>2</sup>.

In a preferred example, the fabric sheet comprises fibers of ultra-high-molecular-weight polyethylene (known as UHMWPE or UHMW). This material is a type of thermoplastic polyethylene with extremely long chains, with a molecular mass usually between 3.5 and 7.5 million atomic mass units. The longer chain serves to transfer load more effectively to the polymer backbone by strengthening intermolecular interactions. This results in a very tough material.

UHMWPE fibers are for example commercially available from the chemical company DSM (trade mark), under the trade name Dyneema (trade mark). When formed into fibers, the polymer chains for example attain a parallel orientation greater than 95% and a level of crystallinity from 39% to 75%.

It is known that UHMWPE is very resistant to UV radiation (as well as to water, moisture, most chemicals and micro-organisms).

The use of UHMWPE fibers in this application is based on the recognition that the fibers are highly (compared to other fibers) transparent to UV light.

The fibers for example have a diameter in the range 2mm to 5mm for example a twine diameter of 3.3mm and weight of in the range 2 to 10 g/m. The fabric is woven in such way as to provide a minimum linear mass density for example of 40 to 200 denier.

The fabric is then opaque or translucent to light in the visible light spectrum so that the LEDs 12 and other components are not visible to the human eye.

By way of example, the fibers have an axial refractive index of 1.59 and a transverse refractive index of 1.53, hence a birefringence of 0.06. They are also highly transparent to infrared, near infrared and radar.

The resulting fabric is for example at least 80% transmissive to UV light, preferably at least 90% transmissive and preferably at least 98% transmissive.

The resulting structure is also opaque (or translucent) to visible light so that the visual appearance of the UV-B LED array is masked. The screen may have a desired visual color and/or pattern, selected for consistency with the décor of the indoor space in which the system is to be used.

5                   The side wall 14 is formed of a boron nitride powder filled polymer. The polymer is for example a silicone or fluoropolymer.

This provides a structure which is highly reflective to UV-B light. For example, a reflection may be achieved of 95% or higher.

10                   The UV-B LEDs are designed to provide a dose of UV-B light which is sufficient to provide the advantages of vitamin D production, but not sufficient to cause skin damage. By way of example, the light intensity of the system as a whole is based on each UV-B LED having an output power of 400 $\mu$ W to 800 $\mu$ W. The total number of UV-B LEDs can be for example in the range 10 to 40 in the panel, giving a total output power in the range 4mW to 30mW.

15                   UV-B LEDs are commercially available, and are mainly used in medical applications, for example for medical photometry. There are also commercially available UV-B lighting products for stimulating plant growth for illuminating terrariums. The UV-B wavelength is in the range 280nm to 315nm.

20                   Figure 2 shows an office space 20 with a ceiling 22 having visible lighting panels 24 (luminaries) and UV-B lighting panels 26 each of the type as described above. In combination, the panels provide the visual lighting required as well as a desired level of UV-B radiation.

The system may be used as part of an office lighting system, but it may also be used for other indoor lighting applications.

25                   The example above makes use of a panel which is dedicated to the generation of UV-B radiation. It is also possible to combine UV-B radiation and visible lighting in the same panel. In such a case, a visually transparent (but typically diffusive) fabric is required so that both UV and visible light can escape from the panel. A diffusive fabric will again mask the appearance of the LED structure beneath.

30                   Other 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. Any reference signs in the claims should not be construed as limiting the scope.



## CLAIMS:

1. An indoor lighting system, comprising:  
a housing (10,14);  
an arrangement of UV-B LEDs (12) in the housing; and  
a fabric output screen (16) which provides a UV-B exit surface,  
5 wherein the fabric output screen (16) is at least partially transparent to UV-B light, and  
wherein the fabric output screen (16) has a linear mass density of between 40 and 200 denier.
2. A system as claimed in claim 1, wherein the fabric output screen (16) is at  
least partially opaque to visible light.
- 10 3. A system as claimed in any preceding claim, wherein the housing comprises a  
base (10) which carries the UV-B LEDs and a side wall (14) around the base, wherein the  
side wall comprises a UV reflector.
- 15 4. A system as claimed in claim 3, wherein the side wall (14) comprises a  
polymer having embedded boron nitride particles.
5. A system as claimed in claim 4, wherein the polymer comprises silicone or a  
fluoropolymer.
- 20 6. A system as claimed in any preceding claim, wherein the fabric (16) of the  
fabric output screen comprises ultra-high -molecular-weight polyethylene fibers.
7. A system as claimed in claim 6, wherein the fibers have a diameter in the  
25 range 2mm to 5mm.
8. A system as claimed in any preceding claim, wherein the fabric output screen  
(16) has an area of more than 1500cm<sup>2</sup>.

9. A system as claimed in any preceding claim, wherein the arrangement of UV-B LEDs (12) comprises between 10 and 40 LEDs

10. A system as claimed in claim 9, wherein each UV-B LED (12) has an output  
5 power in the range 400 $\mu$ W to 800 $\mu$ W.

11. A lighting installation comprising:  
one or more lighting systems (26) as claimed in any preceding claim; and  
one or more visible light luminaires (24).

10

12. A lighting installation as claimed in claim 11, comprising an office lighting  
installation.

13. A lighting installation as claimed in claim 12, wherein the lighting systems  
15 (26) each comprise a ceiling panel and the luminaires (24) each comprise a ceiling panel.

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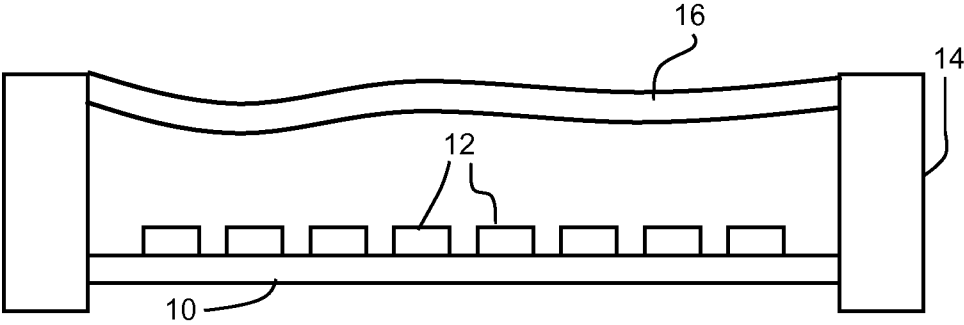


FIG. 1

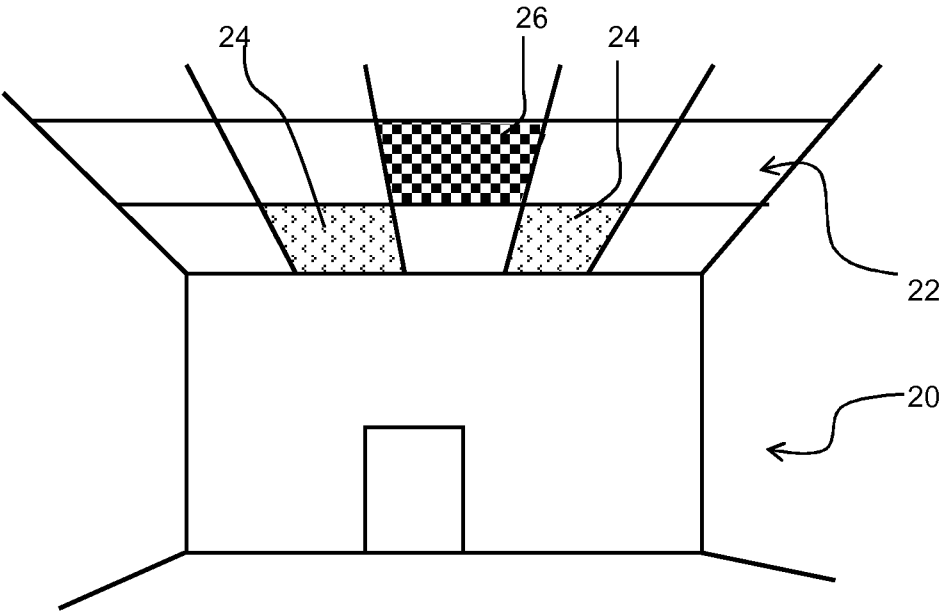


FIG. 2