

DESCRIPTION

[TITLE OF INVENTION]

LIGHTING SYSTEM AND PLANT CULTIVATION APPARATUS

[TECHNICAL FIELD]

[0001] The present invention relates to a lighting system and a plant cultivation apparatus available to hydroponic cultivation and more particularly relates to a lighting system in which light reflected by a cultivation tray surface on which plants are cultivated may be reflect again to the cultivation tray and a hydroponic cultivation apparatus equipped with the lighting system.

[BACKGROUND]

[0002] A room for hydroponic cultivation is kept at relatively high temperature and at high humidity. When a lighting system is placed under such an environment, severe deterioration of the lighting system and shortening of the lifetime thereof may become problems. Thus, the lighting system has been proposed which semiconductor light emitting devices are disposed inside a body and which emits the light through a transparent window of the body, (Refer to Patent Literature 1).

[PRIOR ART LITERATURE]

[0003] Patent Literature 1: JP2010-284127

[SUMMARY OF INVENTION]

[PROBLEM TO BE SOLVED BY INVENTION]

[0004] The lighting system of the above Patent-Literature 1 comprises a reflector encircling LED to which a reflection surface having a paraboloid face is formed and

directions of light emission may be set such that the light can be emitted perpendicular to the transparent cover. Then, the light can shine on the plants with relatively high efficiency.

[0005] However, all of the light emitted from the lighting system cannot shine on the plants and the light shines on the cultivation tray surface etc. The cultivation tray may be formed by plastic resin such as polyethylene and polyvinylchloride or ceramics etc. and may be selected from materials having white color as well as gloss. This is because the cultivation tray does not absorb heat. In this case, the light exposed from the lighting system is reflected on the cultivation tray surface and the reflected light is returned back inside the lighting system as well as escaping around the circumference etc. to cause waste light.

[0006] Furthermore, LED used as the light source is expensive such that it has been desired to decrease numbers of LED as few as possible. When the numbers of LED can be decreased, amounts of coolant for cooling LED may be decreased and electric power supplied to LED also become low.

[MEANS FOR ADDRESSING TO PROBLEM]

[0007] The present invention has been made by considering the above problem and the present invention can provide the lighting system which comprises a plurality of light sources, a body retaining the plurality of the light sources while comprising a transparent window for escaping the light emitted from the light sources, and a reflection member, the reflection member being disposed so as to cover the window for reflecting light from outside of the body while a plurality of holes for launching the

light emitted from each of the light source are formed.

[ADVANTAGEOUS EFFECT OF INVENTION]

[0008] According to the present invention, since the window is covered by the reflection member resting the portions from which the light from the light source escapes, the reflected light from the cultivation tray can be directed efficiently again to the plants cultivated at the cultivation tray, thereby making it possible to supply a predetermined light amount while decreasing the numbers of light sources also decreasing facility costs as well as lowering running costs. Furthermore, since light sources are retained inside of the body, deterioration of the light sources can be prevented so as to lengthening the lifetime thereof.

[BRIEF DESCRIPTION OF DRAWING]

[0009] [Fig. 1] A drawing illustrating an example of a construction of a lighting system according to the present invention.

[Fig. 2] A drawing illustrating a relation between reflection numbers at a reflection sheet and a light amount returned to plants when a light amount emitted from LED is 100 %.

[Fig. 3] A drawing illustrating an example of a construction of a plant cultivation apparatus according to the present invention.

[Fig. 4] A drawing illustrating enlarged another example of a construction of a plant cultivation apparatus.

[Fig. 5] A drawing illustrating another example of a construction of a plant cultivation apparatus according to the present invention.

[Fig. 6] A drawing illustrating a cross section of a lighting system equipped with a water cooling tube along to a width direction thereof.

[Fig. 7] A drawing illustrating a cross section of a lighting system of Fig. 6 along to a longitudinal direction thereof.

[Fig. 8] A drawing illustrating an enlarged cross section of an attachment portion of a LED chip of a lighting system of Fig. 6.

[Fig. 9] A drawing illustrating an exploded plane view of a spacer of a lighting system for explaining combination thereof.

[Fig. 10] Drawings of plane and side views of an end cover member of a lighting system of Fig. 6.

[Fig. 11] A drawing of a cross section of another example for a construction of a lighting system comprising a water cooling tube.

[Fig. 12] A drawing of a cross section of a lighting system comprising a heat dissipation fin along to a width direction thereof as an example of a lighting system comprising a heat removal means.

[EMBODIMENT FOR PRACTICING INVENTION]

[0010] With referencing to Fig. 1 the present lighting system will be described in detail; however, the present invention should not be limited to the constructions depicted in Fig. 1. The lighting system 10 comprises light sources 11, a body 12 retaining the plurality of the light sources 11 while comprising a transparent window for escaping the light emitted from the light sources 11, and a reflection sheet 14 acting as a reflection member, the reflection member being disposed so as to cover the

window for reflecting light from outside of the body 12 while a plurality of holes 13 for escaping the light emitted from each of the light source are formed.

[0011] As the light source 11, a fluorescence light tube or LED etc. may be available.

Here, LED may be desirable as the light source from the low power consumption thereof. The light sources 11, for example, can be formed by four LED chips each of which emits lights independently with red, green, and blue. The color of 4 LED chips composing the light source 11 may be chosen depending on particular applications.

The light source 11 composed from 4 LED chips can be arranged six on one substrate as shown in Fig. 1(a). But the present invention is not limited thereto; numbers of the LED chips can be no more than 4 or not less than 5. Furthermore, the light sources 11 on one substrate can be disposed 5 or less, or not less than 7.

[0012] Not shown in Fig. 1, a light control box for controlling luminance of LED chips for each color can be disposed. The light controlling box can control the luminance for each color independently, or alternatively can control luminance of the LED chips for all color uniformly.

[0013] The light source 11 generates heat when it emits the light. This heat causes heat damages to the plants due to accumulation of the heat in the plant body. Therefore, the heat generated must be removed. The lighting system 10 is implemented such that each of the light sources 11 is placed on the substrate which has a function of a heat sink substrate and a coolant tube is connected to the substrate to remove the heat. In the coolant tube, the coolant is supplied and the heat conducted to the coolant tube through the substrate is absorbed by the coolant. The substrate can include an

aluminum plate or a copper plate etc. The coolant can include ammonia, isobutene, carbon dioxide, water etc. These are exemplarily described; however, other constructions such as, for example, supplying air into the body 12 can be adopted.

[0014] Furthermore, in the circumference of the light source 11, the reflector 15, which makes it possible to emit the light from the light source 11 toward a predetermined direction. The reflector 15 has the reflection surface of which diameter increases with respect to the distance from the light source 11. The reflection surface can have the parabolic curvature such as a parabolic antenna. The reflector 15 can be formed by evaporated metal film of aluminum or silver on an acrylic resin etc. to which an opening for the reflection surface is formed.

[0015] In the embodiment shown in Fig. 1(a), 6 light sources 11 are disposed on the substrate and the reflector 15 is placed such that the reflector 15 covers the substrate. Sixteen substrates each disposed with six light sources 11 are retained in the body 12.

[0016] The body 12 is a box-shaped element comprising the rectangular upper plate 16, four side plates 17 continuous to each edges of the upper plate 16, and the transparent lower plate 18 used for the window. The substrate with six light sources 11 is disposed such that the substrate is sandwiched by the upper plate 16 and the lower plate 18 and the terminal stand 19 is disposed on the upper plate 16 to which the light controlling box for controlling the luminance of LED chips for each colors is connected.

[0017] The upper plate 16 and the side plates 17 are selected from any material so far as they can provide hardness to the lighting system 10 so as to prevent deformation.

For example, the materials may be selected from metals such as aluminum, stainless steel, copper, titanium and plastic materials such as ABS resin etc. Aluminum or aluminum alloy may be suitable because of their superior light weight and costs and the surface may preferably have alumite processing for preventing from the corrosion. From the standpoint of light reflectance and effective use of light, the alumite processing may be white alumite and/or may be applied clear coatings on the alumite processing.

[0018] The lower plate 18 may be selected from any materials so far as the lower plate 18 can pass efficiently the light from the light source 11. For example, the material can include glass as well as an acrylic resin, polycarbonate, and polyethylene terephthalate etc. It may be possible to dispose an anti-reflection film for preventing the light reflection at the side of the lower plate facing to the light source 11.

[0019] When assumed that the light source 11 side of the lower plate 18 is a upper face, the opposite lower face is adhered with the reflection sheet 14. The reflection sheet 14 can be adhered by using an adhesives including the major composition selected from an epoxy resin, a silicone resin, an urethane resin, and an acrylic resin. The reflection sheet 14 reflects the light coming inside of the body 12 from the outside thereof. On the other hand, the hole 13 having the rectangular shape and the same area with the substrate such that the light emitted from each of the light source 11 is allowed to escape to the outside thereof.

[0020] The hole 13 in Fig. 1 (a) is formed by cutting out the reflection sheet 14 because the reflector 15 has high reflectivity and the area thereof is not so large.

However, the present invention may not be limited thereto, each of circles can be independently cut out such that only each of the light sources 11 and the reflection surface about the light source 11 are exposed.

[0021] The lighting system 10 emits the light launched by each of the light source 11 perpendicular to the lower plate 18 composing the window by the reflector 15 and shines on the plants over the window. A part of the irradiated light can be used to perform photosynthesis of the plants. The rest part of the light is returned to the lighting system 10 reflected by the cultivation tray surface. Here, since the direction of the light from the light source is set by the reflector 15, most of the rest light can be returned to the lighting system 10 by the reflection with the cultivation tray surface.

[0022] The light returning to the lighting system 10 is again reflected by the reflection sheet 14 adhered to the lower plate 18 to shine on the plants. Due to the repetition of the above, the light can be used efficiently, thereby the predetermined amounts of light can be supplied while decreasing numbers of the light sources. When the numbers of the light sources 11 is decreased, the power supply thereto is decreased and then the running cost can be decreased. Furthermore, the light sources 11 are retained in the body 12 such that deterioration of the light sources can be prevented to lengthen the lifetime thereof.

[0023] The reflection sheet 14 may preferably have higher reflectivity and the reflectivity not less than 98% may be adopted. In addition, a material of the reflection sheet may be polypropylene as a major raw material because of lighter weight than that of white PET, high resistance to hydrolysis and high weatherability. The reflection

sheet made from polypropylene is preferred because the reflectivity of the light is about 99 % which is higher than that of white PET.

[0024] The reflection sheet 14 may be preferably attached to the cultivation tray surface as well as a lower side of the transparent lower plate 18, because the light can be adequately reflected to the reflection sheet attached to the lower plate 18, thereby the light being used more effectively. In addition, part of the light escapes toward lateral sides. Thus, the light reflection plate may be disposed at the lateral sides to prevent the light escape toward the lateral sides.

[0025] In the body 12, a plurality of light sources 11 are retained and humidity in the body 12 may be preferably kept low when the humidity in the body 12 becomes high, the deterioration of the light sources 11 become severe causing shortening of the lifetime. Therefore, a material having hygroscopicity (absorbent agent) such as a desiccant etc. can be packed in the body 12. The absorbent agent may include active carbon and silica gel, but not limited to, the present invention may use any material which has hygroscopicity. The absorbent agent can be recovered by heating thereof.

[0026] Now, the results of the simulation how the light can be used effectively by attaching the reflection sheet 14. Fig. 2 shows the relation between reflection numbers and light amounts (%) for the case that the reflection sheet 14 is attached and for the case without the reflection sheet 14. The case with attaching the reflection sheet 14 was simulated further two cases that the reflection sheets 14 was attached to both of the lower plate 18 and the cultivation tray surface (case A) and that the reflection sheet 14 was attached only to the lower plate 18 (case B). The simulation for the case

without the reflection sheet was performed by assuming that the reflection sheet 14 was not attached at all (case C).

[0027] The reflection number represents the number of the reflection on the reflection sheet 14 attached to the lower plate 18 and the light amounts (%) is the percentile of the light amounts at each reflection number when the light amounts emitted from the light source 11 is assumed to 100%. That is to say, the summation of the light amounts 100% emitted by the light source 11 and the light amounts % of the reflection light.

[0028] Here in this simulation, it was assumed that the plant absorption ratio was 20%; the reflection ratio of the reflection sheet 14 was 99%; the reflection ratio of the cultivation tray surface was 80% and the reflection ratio of the reflector 15 etc. without attaching the reflection sheet 14 was 50%. The cultivation tray was the tray made of gloss and white vinylchloride; the body 12 comprised by the upper plate 16; the lower plate 17 each of which was formed by aluminum plate and the lower plate 18 is formed by a transparent glass plate.

[0029] In the case C as shown by cross marks in Fig. 2, the light amount becomes almost constant to be 150% at the reflection numbers of 5 and reaches to an equilibrium state. Since the light amounts emitted from the light source 11 is 100%, the residual value to be about 50% is the light amounts based on the reflection light from the cultivation tray. Practically, there is light escape to lateral sides and it may be thought that the light amounts will be lower than 150%. The light escape to the lateral sides may be similar in other cases.

[0030] In the case B as shown by triangle marks in Fig. 2, the light amount becomes

almost constant to be about 270% at the reflection numbers of 10 that is twice of the case C and reaches to an equilibrium state. This light amounts to be about 270% of case B is almost twice of the value to be 150% of the case C. Therefore, about twice light amounts can be obtained only by attaching the reflection sheet 14 only to the lower plate 18. When assumed that the same light amounts with that of the case C is obtained, the numbers of the light sources 11 will be decreased to one-half of the case C.

[0031] In the case A, the equilibrium state is not reached when the reflection number is fourteen. Furthermore, the light amount at the reflection number of 14 is to be about 450% and this value is about triple to the case C. This means that the light amounts can be increased largely by attaching the reflection sheet 14 to the cultivation tray surface and as the result thereof the numbers of the light source 11 necessary for obtaining the same light amounts can be decreased significantly. That is to say, when assumed that the light amount is desirable to be same with that of the case C, the numbers of the light source 11 can be decreased as low as one-third.

[0032] Hereinabove, the lighting system 10 for the hydroponic cultivation has been explained, the present invention may be possible to provide a plant cultivation apparatus 20 comprising the lighting system 10. The plant cultivation apparatus 20 comprises at least one gutter member 21 to which a cultivation solution is supplied, a cultivation tray 22 placed adjacent to each other on at least one gutter 21, a cultivation shelf 23 to which at least one gutter member 21 is placed slant to a longitudinal direction and the lighting system 10 is attached. Furthermore, the plant cultivation

apparatus 20 also comprises a circulation pump 24 as the cultivation solution supply means that supplies the cultivation solution into each of gutter member 21, a cultivation solution tank 25 as a reservoir of the cultivation solution, and an air pump 26 as a gas supply means for sending the air to the cultivation solution.

[0033] The gutter member 21 may be, for example, a commercially available rain gutter and may be placed such that the rain gutter member 21 has a gradient to be about 1%. Thus, the cultivation solution is supplied to a higher side of the gutter member 21 by the supply pump 24 and the cultivation solution flows to an opposite lower side along with an inner surface of the gutter member 21. At the opposite side of the gutter member 21, a discharge port is disposed for discharging excess cultivation solution and a solution collector is disposed under the discharge port. The cultivation solution collected in the solution collector is returned to the cultivation tank 25. Also the gutter member 21 is disposed such that a plurality of gutter members are arranged parallel.

[0034] The cultivation tray 22 is disposed to cross the gutter members parallel aligned gutter members 21 over the gutter members 21. The cultivation tray 22 has holes for planting the plants at a constant spacing and a sponge is put in the hole. Over the cultivation tray 22, leaves of the plants grow and roots of the plants expand under the cultivation tray 22. The roots are held in the gutter member 21 and tops of the roots are immersed in the cultivation solution flowing along with the inner surface of the gutter member 21.

[0035] The plants absorbs cultivation nutrients and water from the tops of the roots and intake thereof into its body and the leaves perform photosynthesis by absorbing the

light to grow. The cultivation solution can include nitrogen, phosphorous acid, potassium and calcium as well as water and oxygen.

[0036] The lighting system 10 is disposed at a upper portion of the cultivation tray 22.

The lighting system 10 is attached with the reflection plate 14 at the lower plate providing the window and it is preferred that the reflection sheet is attached on the cultivation tray 22. In addition, the lateral side of the cultivation shelf 23 is illustrated such that the side is opened; however, it is preferred that the side is closed by a reflection plate from the point of view for effective usage of the light.

[0037] The reflection plate comprises reflection plate which closes the lateral sides of the plants planted to each of the cultivation trays 22 and prevents the light from the lighting system 10 placed above and the light reflected from the cultivation trays 22 from escaping to the lateral sides while reflecting the light again toward the plant.

[0038] For example, as shown in Fig. 4, the reflection plate 27 may be attached to the surface of the cultivation tray 22 opposing to the reflection surface of the reflection sheet 14 and the reflection plate 28 may be disposed such that the lateral side of the plants planted to the cultivation tray 22 is closed. The reflection plate 28 may be formed by adhering the reflection sheet 14 to a plate shaped material such as wood, plastic resins, ceramics etc. and the reflection plate 28 may be disposed to the cultivation shelf 23 by fastening means such as bolts and nuts.

[0039] The plant cultivation apparatus 20 may be disposed in a room and may comprise a circulation fan as the air circulation means for circulating the air to keep the temperature in the room constant. Also the plant cultivation apparatus 20 may

comprise a dehumidifier as a humidity control means for controlling humidity at constant because the humidity in the room becomes high due to evaporation of the cultivation solution and breathing of the plants. Furthermore, the plant cultivation apparatus 20 may comprise a ventilation fan as ventilation means for exhausting the air inside the room to outside while taking outside air. The plant cultivation apparatus 20 may comprise a filter etc. as a floating substance removal means for removing fungus and/or dust floating in the air when taking the outside air.

[0040] Also the plant cultivation apparatus 20 may arrange the plurality of cultivation trays 22 put over the gutter member 21 such that the cultivation trays 22 are lined up with respect to early harvest timing, thereby realizing continuous harvest by transferring the cultivation trays at the harvest timing to a harvesting place and new cultivation trays are added at the opposite side.

[0041] When lined up as described above, it is desirable to change the number of the light source 11 depending on growth of the plants. Because plants require different light amounts depending on the growth stage thereof. That is to say, it is desired that much more light amounts are provided to plants having lot of grown leaves and being near to the harvest timing and less light amounts are provided to plants being just come up and having small leaves. By setting such adequate light amounts, the number of the light sources 11 may be decreased as the results in turn apparatus costs and running costs may be decreased.

[0042] For example, the gutter members 21 are divided into three region along with the longitudinal direction thereof. With respect to the region of one side to which the

cultivation trays planted with plants having yet small leaves are placed, the lighting system 10 with less numbers of the light sources 11 as shown in Fig. 1 (a) may be equipped. With respect to the region of the center to which the cultivation trays planted with plants somewhat grown are placed, the lighting system 10 with larger numbers of the light sources 11 as shown in Fig. 5 (a) than the lighting system of Fig. 1 (a) may be equipped.

[0043] Furthermore, with respect to the region of another side to which the cultivation trays planted with plants having lot of grown leaves are placed, the lighting system 10 with much larger numbers of the light sources 11 as shown in Fig. 5 (b) than the lighting system of Fig. 5 (a) may be equipped. The arrangements of the light sources 11 shown in Fig. 5 are illustrated as one example and any other arrangements may be allowed. In addition, the numbers of the light sources 11 may be much or less than the described in the figures as long as the numbers of the light sources 11 may be increased as the series of Fig. 1 (a), Fig. 5 (a) and Fig. 5 (b). Alternatively, rather than increase or decrease the numbers of the light sources 11 all of the numbers of the light sources 11 is set to be same and the light amounts emitted by the individual light source 11 may be controlled.

[0044] The numbers of regions divided along with the longitudinal direction of the gutter member 21 cannot be limited thereto, and the numbers may be two or not less than four. By subdividing the regions to not less than four, fine light amounts control may be attained.

[0045] The lighting system of the present invention, as described above, can comprise

means such as a heat dissipation substrate or a coolant tube for removing the heat generated by the light source 11. An example of the lighting system comprising the means for removing the heat described above may include a lighting system equipped with a water cooling tube and a lighting system equipped with a heat dissipation fin. With referring to Fig. 6-Fig. 12, detailed constructions of the above lighting system will be explained. First, the lighting system comprising the cooling tube will be explained with referring to Fig. 6-Fig. 10.

[0046] Fig. 6 shows the cross sectional view of the lighting system comprising the cooling tube along with the width direction thereof. Fig. 7 shows the cross sectional view of the identical lighting system along with the longitudinal axis perpendicular to the width. The lighting apparatus comprises the cooling panel 30 having almost rectangular shape. The cooling panel 30 is composed from the heat dissipation substrate 31 and a hollow part 32 integrally disposed to the heat dissipation substrate 31 and disposed on the upper surface at the center of the width direction thereof.

[0047] The cooling panel 30 can be formed by an extrusion molding with for example aluminum and/or copper etc. which are metal materials having high thermal conductivity. Inside of the hollow part 32 the water passing tube 33 made of the metal materials having high thermal conductivity such as aluminum or copper is inserted. The water passing tube 33 is fixed to the inside of the hollow part 32 by enlarging the diameter of the tube. In the water flowing tube, the cooling fluid such as water etc. is passed. The cooling fluid may include gases such as air or carbon dioxide or brines etc. using the major component of ethyleneglycol or propyleneglycol etc.

[0048] The lighting system comprises a plurality of the LED emission units 34 which are attached on the lower surface of the cooling panel 30 and arranged in the 2 banks. Hereafter, the explanation is made by assuming that the lower surface refers to the surface of the side that the hollow part 32 is not protruded and the upper surface is refers to the surface of the lower opposite side. The LED emission unit 34 comprises a plurality of LED chips 35 as the light sources 11, the secondary reflector 36 having the mirror reflector 36a attached surrounding each of the LED chip 35. The LED emission unit 34 is not limited to 2 banks and 1 bank or not less than 3 banks may be allowed.

[0049] The LED chips 35 are directly connected to the lower surface of the cooling panel 30, i.e. the heat dissipation substrate 31. For the contacting to the lower surface, a silicone adhesive agent or a silver paste having high thermal conductivity may be used. The heat dissipation substrate 31 is cooled by removing the heat the coolant water flowing inside of the water flow tube 33. Then, the heat generated by the LED chip 35 is quickly absorbed by the heat dissipation substrate 31 to suppress the heat-up of the LED chip 35.

[0050] As for the LED chip 35, the LED chip, to which the emission part made from Gallium nitrate system on a sapphire substrate. According to the present invention, the LED chip 35 having the peak wavelength of 660 nm, i.e. red light may be preferred because the availability of the photosynthesis of plants is the best.

[0051] Furthermore, the lighting system comprises the spacer 38 at the part of the circumference edges of the cooling panel 30, i.e. the part near the both edges along to the width direction and the lower surface of the part near to the both edges along with

the longitudinal direction of the heat dissipation substrate 31 and the spacer 38 is bonded by the primary sealing material 37. The spacer 38 may be made from metal materials such as for example aluminum or copper having high thermal conductivity by the extrusion molding. The primary sealing material 37 may be an adhesive sealing tape.

[0052] The lighting system further comprises the transparent light transparent plate 39 which is disposed to the opposing LED attaching surfaces to which the LED chip of the cooling panel 30 is attached. The light transparent plate 39 is connected to the spacer 39 by the primary sealing material 37 on the part near the circumference edges, i.e. the part near the both edges along to the width direction and the part near to the both edges along with the longitudinal direction. The light transparent plate 39 may be any type of a transparent having a plate shape such as for example, a glass plate or a synthetic resin plate selected from a polycarbonate resins etc.

[0053] To the lighting system, the reflection sheet 40 as a reflection member is attached on the lower surface of the light transparent plate 39 etc. The reflection sheet 40 may be attached as described above by using an adhesion agent comprising a major component such as an epoxy resin, a silicone resin, a urethane resin, an acrylic resin etc. The reflection sheet 40 reflects the light coming into the inside of the lighting system from the outside thereof. On the other hand, the reflection sheet 40 comprises the holes 41 being cut out and having almost same area with the area of the light launching port which has a rectangular shape same with the light transparent plate 39 and has an enlarged diameter for launching the light formed by the secondary reflector

36. The hole 41 can emit the light generated by the LED chip 35 outside through the light transparent plate 39.

[0054] The reflection sheet 40 may have preferably high reflectivity and can be adopted that having the reflectivity not less than about 98%. The material for the reflection sheet may be the white PET which is popularly used and has about 98% reflectivity. In addition, the reflection sheet 40 may be those including polypropylene as a major component with lighter weight than that of white PET and with high hydrolysis resistance while having excellent weatherability. The reflection sheet made of polypropylene is preferred because the light reflectivity is about 99% which is higher than that of the white PET.

[0055] Therefore, in this embodiment, the body 12 has the construction packing the light sources 11 and comprising the panel 30 being attached with light sources 11, the spacer 38 connected to the cooling panel 30 through the primary sealing material 37 and disposed circumferentially about the light sources 11, and the light transparent plate 39 which is disposed opposite to the lower surface of the heat dissipation substrate 31 and is connected to the spacer 38 through the primary sealing material 37.

[0056] Now with referring to the cross sectional view of Fig. 8, the attachment part for the LED chip 35 will be detailed. The LED chip 35 has the construction for conducting the heat generated to the back side efficiently using a chip-on board (COB) implemented directly on the heat dissipation substrate 31.

[0057] The LED emission unit 34 is formed as follows: the dielectric layer 50 is laminated on the heat dissipation substrate 31 through the bonding layer 51. On the

dielectric layer 50 the wiring part 52 including the copper sheet formed to the circuit pattern is laminated to form the circuit board 53. To this circuit board 53 the LED attachment holes 54 with inverted taper shape are formed for a predetermined numbers with a given spacing and circular primary reflector 55 having the white high reflection surface is disposed to the inner surface of each of the LED attachment holes 54.

[0058] Next, the LED chip 35 is connected to the bottom of each of the LED attachment hole 54, i.e. on the heat dissipation substrate 31 and the bonding wire 56 is disposed for contacting the LED chip 35 and the wiring part 52 electronically. The bonding wire 56 is the wire formed by gold, aluminum or copper etc. Finally, the transparent sealing resin 57 is filled in the LED attachment hole 54 for covering the LED chip 35 and bonding wire 56. Here, the transparent sealing resin 57 may include an acrylic resin, an epoxy resin and silicone resin etc.

[0059] The LED emission unit 34 as such formed is easy to form and provides good productivity since the wiring plate 53 can be formed without any processing to the planer surface of the heat dissipation substrate 31. In addition, known various metal plates may be used and the contact of the LED chip 35 is also good since any processing to the heat dissipation substrate 31 for forming concaves or protrusions are not necessary. In addition, it is preferred that the thickness of the wiring plate 53 is set thinner than the thickness of the LED chip 35 because the light can be guided downward.

[0060] Again referring to Fig. 7, the LED emission unit 34 is fixed to the lower surface of the cooling panel 30, i.e. the lower surface pf the heat dissipation substrate

31.

[0061] The spacer 38 is composed from 8 members as shown in Fig. 9 and is assembled by using the above members. The 8 members are 2 vertical members 38a, 2 lateral members 38b, and 4 corner members 38c. The spacer 38 is assembled such that 2 vertical members 38a and 2 lateral members form the rectangular shape and the rectangular shape is connected at corner parts by 4 corner members 38c made from a synthetic resin. Each of the corner members 38c comprises the first insert part to which one side of each two vertical members 38a is inserted; the second insert part to which one side of each of two lateral members 38b is inserted and the intermittent connection part being bent to about 90 degrees and for connecting the first insert part and the second insert part.

[0062] The spacer 38 formed by inserting each vertical member 38a and each lateral member 38b to each of the insert part is fixed with the cooling panel 30 through the first sealing material 37 on the upper side and with the light transparent plate 39 through the first sealing material 37 on the lower side. Through holes for ventilation are formed to the inner wall of the spacer 38 opposing to the LED emission unit 34 when the spacer 38 is disposed in the lighting system. To the hollow part in the spaces 38 the moisture absorbent such as activated carbon, silica gel or molecular sieves etc. is filled.

[0063] Again referring to Fig. 6 and Fig. 7, the secondary sealing material 60 is filled to the void space formed between the cooling panel 30 and the transparent plate 39 for all outside circumference of the spacer 38. The chamfer concave part 38d is formed to

the upper and lower edges at the outside wall of the spacer 38 along the length thereof to fit the inner convex part 60a at the upper and lower edges of the secondary sealing material 60.

[0064] The frame member 61 with the groove shape for covering to fit is attached to both edges along with the width direction of the cooling panel 30 and the light transparent plate 39 and the secondary sealing material 60 filled therebetween. The frame member 61 is formed by the upper wall part 61a, the lower wall part 61b and the vertical wall part 61c connecting therebetween and the cross sectional shape has a rectangular with one edge is removed. The ridge 61a toward inside for screw-in having the C-letter like cross sectional shape is formed at the vertical center of the vertical wall part 61c along to the all length of the frame member 61.

[0065] The lower fitting ridge 61e having an arch shaped cross section is formed along with the total length of the inner end portion of the upper wall part 61a of the frame member 61. Correspondingly thereto, both end portions along with the width direction of the heat dissipation substrate 31 of the cooling panel 30 are formed to thin and each of the upper surface of both thin end portions have the fitting concave part 31a with an arch shaped cross section. The cooling panel 30, the light transparent plate 39, and the second sealing member 60 are secured each other by the frame member 61.

[0066] For fixing the frame member 61 so as to cover the above members, it is desirable that the secondary sealing 60 is soft. In this condition, the ridge 61d for screw-in disposed to the vertical wall part 61c of the frame member 61 is pressed into the secondary sealing material under the soft condition thereby the secondary sealing

material 60 is sandwiched and pressed by the vertical wall part 61c and the spacer 38 to deform the vertical center portion of the secondary sealing material 60. In addition, the ridges 60a toward inside are formed at both vertical end portion of the secondary sealing part 60 and the ridges 60a toward inside fit to the chamfered concave part 38d of the spacer 38. Then, after the cure of the secondary sealing material 60, much more secure sealing is realized.

[0067] The lighting apparatus comprises as shown in Fig. 7 and Fig 10 (a), (b) the cover member 62 with a cross section of about L-letter. The cover member 62 is disposed to cover the secondary sealing material 60 at the longitudinal both ends of the cooling panel 30 and the light transparent plate 39. The cover member 62 is composed by the vertical wall part 62a and the horizontal part 62b continuous to the lower end of the vertical wall part 62a. The portions around the both ends of the vertical wall part 62a are disposed with through holes 62c for insertion of tapping screws.

[0068] The cover member 62 is placed to cover the secondary sealing material 60 at the both ends along with the longitudinal direction with the horizontal part 62b outside. The cover member 62 is connected by inserting the tapping screw to the through hole 62c and then screwing in the tapping screw to the ridge 61d toward inside for screw-in with the cross section of about C-letter formed to the frame member 61.

[0069] Also fixing of the cover member 62 is desirably performed when the secondary sealing member 60 is soft. That is, the cover member 62 and the spacer 38 hold the secondary sealing material 60 under pressure to deform the secondary sealing material 60 and the ridges toward inside 60a are formed at both of the upper and lower ends.

These ridges toward inside 60a engages to the chamfered concave part 38d of the spacer 38 and after that the secondary sealing material 60 is cured thereby realizing much more secure sealing.

[0070] As the lighting system comprising the water cooling tube illustrated in Fig. 11, the engagement part 70 having the cross section of C-letter shape is integrally formed on the upper surface of the cooling panel 30 and the water flowing pipe 33 may be engaged by pressure to attach thereto.

[0071] Although the lighting system shown in Fig. 6 or Fig. 11 is the type that the system is water cooling type with the water flowing tube 33 fixed to the hollow part 32 or the engagement part 70 which are formed integrally with the heat dissipation substrate 31, an air cooled system may be possible to remove the heat. Fig. 12 shows the cross sectional view along with the width direction of the lighting system comprising the heat dissipation fin 80 integrally with the heat dissipation substrate 31 as the air cooling type one.

[0072] In the lighting system comprising the heat dissipation fin 80, the cooling panel 30 is composed from the planer heat dissipation fin 31 and the plate shaped fins 80a extending vertically to one side of the heat dissipation substrate 31, i.e. the upper surface. The fins 80a are disposed to have a given spacing. When the root is referred to the portion that contact to the heat dissipation substrate 31, the fin 80a may be formed to have the same thickness from the top to the root or to have thicker thickness from the top to the root for providing a given fin strength. The cooling panel 30 comprising fins 80a may be formed by the extrusion molding using the metal materials such as

aluminum or copper having high thermal conductivity.

[0073] The air pass through air-passing gaps formed between the fins 80a and the fins 80a are cooled by contacting to the air. Accordingly, the heat dissipation substrate 31 continuous to the fins 80a is cooled. Thus the heat generated by the LED chip 35 can be absorbed to the heat dissipation substrate 31 and the heating of the LED chip 35 can be suppressed.

[0074] The fins 80a described above have been explained to have the plane shape; however, the fins 80a may have a stick shape. Here, the fins 80a may be formed to adequate thicknesses and lengths such that the fins 80a are disposed with adequate distances and can pass adequately the air therebetween to suppress the heating of the LED chip 35.

[0075] The lighting system can comprise the cover 81 to cover the fins 80a. The cover 81 can be prepared to avoid depositions of dusts and/or soils of the fins 80a. The cover 81 may be fixed to the cooling panel 30 by screws etc. (not shown). Also this cover 81 may be formed with using aluminum or copper having high thermal conductivity by the extrusion molding.

[0076] Other components may be the same with those of the lighting system exemplarily illustrated in Figs. 6-10.

[0077] The lighting system comprising a means for removing the heat shown exemplarily in Figs. 6-12 packages the LED unit 34 by the cooling panel 30, the spacer 38 and the light transparent plate 39 etc. and then the LED device and electronic circuits can be protected while providing high durability to the usage environment

under high humidity condition of the plant cultivation apparatus etc. In addition, since the reflection sheet 40 is attached, the light reflected by the cultivation surface can be again reflected multiply and efficiently to the plants planted at the cultivation tray.

Furthermore, temperature rise in the cultivation space when reflecting the light multiply to the plant can be suppressed by removing the heat with the above means.

[0078] As the result thereof, deterioration of the light source to lengthen the lifetime thereof, thereby decreasing the number of the light sources while reducing the size of the cultivation space by avoiding extra spacing between the light source and the plants. Particularly, economical applicability of the plant factory may be enlarged because the durability of the light sources can be enhanced and the cultivation space can become compact.

[0079] Hereinabove, the lighting system and the plant cultivation apparatus comprising the lighting system of the present invention has been explained by using the above described embodiments; however, the present invention shall not be limited to the above embodiments. Changes, which a person skilled in the art may be reached, such as other embodiments, additions, modifications, and removals may be allowed; however, any embodiment may be included in the scope to the present invention so far as works and advantage of the present invention should be obtained.

[EXPLANATION OF SIGNS AND NUMERALS]

[0080] 10-lighting system, 11-light source, 12-body, 13-hole, 14-reflection sheet, 15-reflector, 16-upper plate, 17-side plate, 18- lower plate, 19- terminal stand, 20- plant cultivation apparatus, 21- gutter member, 22- cultivation tray, 23- cultivation

shelf, 24- circulation pump, 25- cultivation solution tank, 26-air pump, 27-reflection sheet, 28-reflection plate, 30-cooling panel, 31- heat dissipation substrate, 31a-engagement ridge, 32-hollow part, 33-water flowing tube, 34- LED emission unit, 35- LED chip, 36- secondary reflector, 36a- mirror reflection part, 37- primary sealing material, 38- spacer, 38a- vertical member 38b- lateral member, 38c- corner member, 38d- chamfer concave part, 39- light transparent plate, 40- reflection sheet, 41- hole, 50- dielectric layer, 51- bonding layer, 52- wiring part, 53- circuit board, 54- LED attachment hole, 55- primary reflector, 56- bonding wire, 57- sealing resin, 58- screw, 60- secondary sealing material, 61a- upper wall part, 61b- lower wall part, 61c- vertical wall part, 61d- ridge toward inside for screw-in, 61e- lower fitting ridge, 62- cover member, 62a- vertical wall part, 62b- horizontal part, 62c- through hole for inserting tapping screw, 70- engagement part, 80- heat dissipation fin, 80a- fin, 81- cover

CLAIMS

[Claim 1]

A lighting system comprising:

a plurality of lighting sources;

a cooling panel to which a plurality of the light sources are attached;

a spacer disposed such that the spacer is disposed surrounding a plurality of the light sources and being bonded to the cooling panel through a sealing material;

a body which is disposed opposing to an attachment surface of a plurality of the light sources being attached to the cooling panel while comprising a light transparent plate which is connected to the spacer through a sealing material to seal the light source, retaining the plurality of the light sources while comprising a transparent window for escaping the light emitted from the light sources; and

a reflection member being disposed so as to cover a window for reflecting light from outside of the body while a plurality of holes for launching the light emitted from each of the light sources are formed.

[Claim 2]

The lighting system of claim 1, wherein the reflection member is a reflection sheet which is attached to a window and a reflectivity of the reflection sheet is not less than 98 %.

[Claim 3]

The lighting system of claim 1 or 2, wherein a material having a humidity absorption property which is packed in the body.

[Claim 4]

The lighting system of any one from claim 1 to 3, wherein the cooling panel comprises a hollow part at a back side of the attachment surface of a plurality of the light sources and is cooled by a cooling fluid flowing in the hollow part.

[Claim 5]

The lighting system of claim 4, wherein the lighting system further comprises a water flowing tube passed through the hollow part to flow the coolant fluid therein.

[Claim 6]

The lighting system of any one from claim 1 to 3, wherein the cooling panel comprises an engagement part at a back side of the attachment surface for a plurality of the light sources and the water flowing tube is fixed by pressing in the water flowing tube into the engagement part.

[Claim 7]

The lighting system of any one from claim 1 to 3, wherein the cooling panel comprises a heat dissipation fin and a plurality of the heat dissipation fins being arranged at a given spacing at the back side of the attachment surface for a plurality of the light source.

[Claim 8]

A plant cultivation apparatus comprising:

at least one gutter member;

a cultivation shelf to which at least one gutter member is placed slant to a longitudinal direction;

a plurality of the cultivation tray placed adjacent to each other on at least one gutter;

a cultivation solution supply means that supplies the cultivation solution into each of the gutter member; and

a lighting system of any one from claim 1 to 7 for shining light to the plants planted on a plurality of the cultivation tray.

[Claim 9]

The plant cultivation apparatus of claim 8, wherein the plant cultivation apparatus comprises a reflection plate comprising a reflection surface for reflecting the light from the lighting system and the light reflected by a surface of a plurality of the cultivation tray and disposed so as to close a side of a plurality of the cultivation tray to which the plants are planted thereon.

[Claim 10]

The plant cultivation apparatus of claim 8 or 9, wherein the cultivation tray is paced such that the cultivation trays are placed in a series of growth of the plants along with a longitudinal direction of at least one of the gutter member and the gutter member is categorized into at least two region along to the longitudinal direction and the lighting systems comprises at least two lighting systems for the regions each of which comprises

different numbers of light sources determined depending on growth of the plants.

[Claim 11]

The plant cultivation apparatus of any one from claim 8 to 10, wherein the plant cultivation apparatus further comprises gas supply means for supplying oxygen to the cultivation solution,

[Claim 12]

The plant cultivation apparatus of any one from claim 8 to 11, wherein the plant cultivation apparatus is placed in a room and further comprises an air circulation means for circulating the air on the room, a humidity control means for controlling the humidity in the room, and a floating substance removal means for removing the floating substances in the room.