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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 November 2008 (27.11.2008)

PCT

(10) International Publication Number
WO 2008/143482 A2

(51) International Patent Classification:
H01L 31/04 (2006.01)

(21) International Application Number: PCT/KR2008/002898

(22) International Filing Date: 23 May 2008 (23.05.2008)

(25) Filing Language: Korean

(26) Publication Language: English

(30) Priority Data:
10-2007-0050379 23 May 2007 (23.05.2007) KR
10-2007-0093580 14 September 2007 (14.09.2007) KR
10-2007-0094000 17 September 2007 (17.09.2007) KR

(71) Applicant and
(72) Inventor: **KIM, Hyun-Min** [KR/KR]; 344-6, Yangjae 2-dong, Seocho-gu, Seoul 137-897 (KR).

(74) Agent: **YOON, Eui-Seoup**; 17F UNIK Bldg., 706-13 Yoksam-dong, Kangnam-gu, Seoul 135-080 (KR).

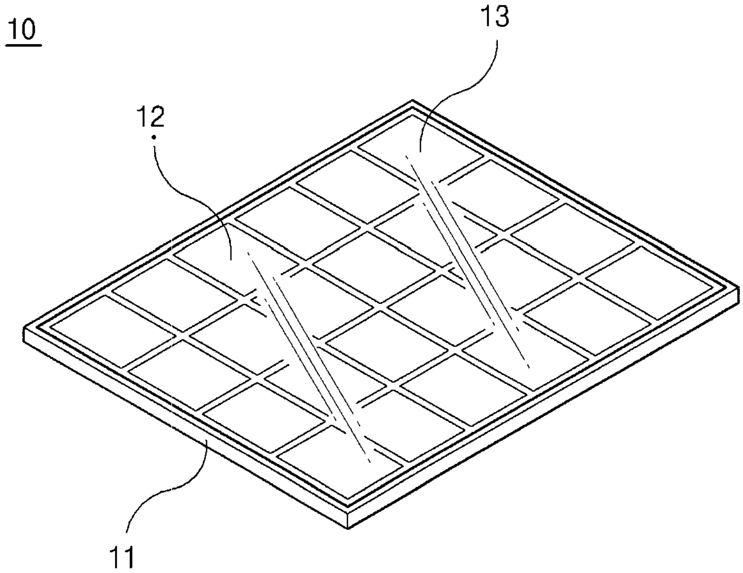
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM,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

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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

(54) Title: SOLAR CELL MODULE FOR ROOF AND APPARATUS FOR COLLECTING SOLAR ENERGY USING THE SAME

Fig. 1



(57) Abstract: A solar cell module for a roof and an apparatus for collecting solar energy using the same are provided, which can efficiently collect solar energy. The solar cell module for a roof includes a main body mounted on a roof panel, a solar panel, a temperature sensor installed on the solar panel, and a cooling means for cooling the solar panel by compulsorily making cooling fluid flow between the solar panel and the bottom surface of the main body. The apparatus for collecting solar energy includes a solar cell module for a roof having the above-described construction, a electric conversion device connected to a solar panel, a heat sink control part for driving the cooling means when a temperature sensed by the sensor exceeds a specified temperature, and a heat recovery part for recovering heat energy from the heated cooling fluid.

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TITLE : SOLAR CELL MODULE FOR ROOF AND APPARATUS FOR COLLECTING SOLAR ENERGY USING THE SAME

Technical Field

The present invention relates to a solar cell module which is mounted on a roof of a building to collect solar energy (electricity and/or heat) and an apparatus for collecting the solar energy using the same.

Background Art

Due to the global worming resulted from massive use of fossil fuels or environmental destruction, unusual change in the weather happens. As a scale of natural disaster is increased, the development and use of alternative energy has been actively progressing. In particular, a solar energy collecting apparatus is in the limelight due to clean energy and economical efficiency.

The field of collecting and using the solar energy is mainly classified into two groups, that is, a field of solar heat which collects solar heat and uses it for heating or hot water supply, and a field of solar power generation which generates an electric power by using a photoelectric effect in which sunlight enters on a solar cell composed of silicon semiconductors to generate electricity. At an initial stage, the field of solar heat which collects the solar heat and uses it for heating or hot water supply has been studied and developed commercially. In recent, with the development of technology related to a solar cell, the study on the field of solar power generation has been increased.

The solar cell for solar power generation is made in a module of panel type, as shown in FIGs. 1 and 2, and then several solar cell modules 10 are connected to each other in all directions to form a solar power generating apparatus.

The solar cell module 10 includes, as shown in FIG. 1, a panel type frame 11, a plurality of solar cells 12 arranged on the upper surface of the frame 11, and a flat lighting window 13 made of low-iron tempered glass and disposed on the upper surface of the frame 11 to cover the solar cells 12. Although not shown in the drawing, a weatherproof and a filler (EVA) are provided under the solar cells 12. A receptacle 14 for outputting the electric power generated by the solar cells 12 is provided on a rear side of the solar cell module 10, as shown in FIG. 2, and a plurality of fastening holes 13a are formed on a rear flange of the frame 11.

In a case of the solar cell used for power generation, although technology for lowering a cost has been developed, the supply of the solar cells still does not meet the demand due to security of raw material and limit of the technology development. Recently, a cost of the solar cell rises, and the solar cell is in short supply. It causes a production cost of the solar cell module to increase, which impedes the spread of the solar power generation.

Otherwise, the solar cell module as described above is not provided with a cooling means or a heat dissipation means in order to address a temperature of the solar cell which is raised by accumulation of radiant heat. The solar cell module is spaced apart from a roof in order to cool the module using natural ventilation. The structure cannot sufficiently cool the solar cells using the natural ventilation in days of high solar radiation. Consequently, the surface of the solar cell is overheated, which decreases the power generating capability and deteriorates the solar cells to shorten its lifespan. In general, it is informed that as a temperature of the surface of the crystalline solar cell is raised by 1℃ above 25℃, the efficiency of power generation is decreased by about 0.4% to 0.6%.

The conventional solar cell module is formed in a thin panel type, and should be spaced apart from the roof at a certain interval for the natural ventilation. Consequently, the solar cell module is mounted on a beam structure firmly installed on the roof. It increases an installation period and cost, and it spoils the appearance of the building since the solar cell module spaced apart from the roof does not suit the roof.

The plurality of solar cell modules arranged adjacent to each other are electrically connected to each other via cables of power terminal boxes provided on a rear side thereof. To this end, since an operator connects the cables of all power terminal boxes one by one, an installation time is required, and the connection operation is cumbersome.

Disclosure

Technical Problem

Therefore, the present invention has been made in view of the above-mentioned problems.

An object of the present invention is to provide a solar cell module for a roof which, if a temperature of a solar cell exceeds a specific level, the solar cell is compulsorily cooled to prevent an efficiency of power generation from being lowered and prevent deterioration of the solar cell.

Other object of the present invention is to provide a solar cell module for a roof which can easily connect a plurality of solar cell modules without performing connection operation.

Another object of the present invention is to improve a power generating capability by condensing sunlight onto a solar cell panel at a center portion of a solar cell module which is covered by a round lighting window with a Fresnel lens formed on an inner surface thereof.

Technical Solution

In order to achieve the above and other objects, there is provided a solar cell module for a roof comprising: a main body mounted on a roof panel; a solar cell panel arranged apart from a bottom surface of the main body; a temperature sensor installed on the solar cell panel to measure a temperature thereof; and cooling means for cooling the solar cell panel by compulsorily making cooling fluid flow between the solar cell panel and the bottom surface of the main body.

In a preferred embodiment of the present invention, an engaging groove is formed on the bottom surface of the main body to receive a protrusion of the roof panel, and the solar cell panel is disposed at a certain slope to the bottom surface of the main body in one direction.

In a preferred embodiment of the present invention, an insulator material is filled in an interior of the main body to prevent radiant heat from being conducted to the solar cell panel from the bottom surface of the main body and the roof panel.

In a preferred embodiment of the present invention, a heat sink is installed on a power portion of the solar cell panel to come in contact with the solar cell panel, so that the heat sink receives the heat from the solar cell panel, and a temperature sensor is installed on a side portion or lower portion of the solar cell panel or the heat sin.

In a preferred embodiment of the present invention, the cooling means is installed in such a manner that the cooling means comes in thermally contact with the heat sink, and has a cooling pipe through which a cooling fluid flows, an inlet port and an outlet port being formed on both sides of the main body. The cooling means includes a pump communicated with the cooling pipe to compulsorily feed the cooling fluid in the cooling pipe when a temperature detected by the temperature sensor exceeds a specific level.

In a preferred embodiment of the present invention, the cooling means includes a ventilation channel interposed between the bottom surface of the main body and the heat sink and having an inlet port and an outlet port at both sides of the main body. The cooling means further includes a plurality of cooling fins extended downwardly from the heat sink and disposed over the ventilation channel. The cooling means further includes a blower communicated with the ventilation channel to compulsively circulate air in the ventilation channel when a temperature of the solar cell panel detected by the temperature sensor exceeds a specific level.

The solar cell module may further comprise a receptacle installed on a side of the main body and electrically connected with the solar cell panel and the temperature sensor. When two or more solar cell modules are disposed adjacent to each other, the receptacle electrically connects the solar cell panel and a temperature sensor of each solar cell module.

The solar cell module may further comprise a round lighting window installed on an upper portion of the main body to close and seal the solar cell panel. A Fresnel lens pattern is formed on an inner surface of the lighting window to refract sunlight, the solar cell panel is positioned on an upper center portion of the main body, and reflectors are on both sides of the solar cell panel to reflect the sunlight entering around the solar cell panel towards the inner surface of the lighting window.

In a preferred embodiment of the present invention, the lighting window includes a first condenser and a second condenser, in which the first condenser is installed on the upper portion of the main body, and has an area wider than that of the solar cell panel, a Fresnel lens pattern being formed on an inner surface of the first condenser, and the second condenser is installed in the first condenser to cover the solar cell panel, a convex lens being formed on an inner surface of the second condenser. The sunlight reflected by the reflector towards the inner surface of the first condenser is again reflected by the inner surface of the first condenser, is refracted by the second condenser, and is condensed onto the solar cell panel.

The solar cell module may further comprise a heat sink installed on a power portion of the solar cell panel to come in contact with the solar cell panel, and a temperature sensor installed on a side portion or lower portion of the solar cell panel or the heat sin. The cooling means includes a pump communicated with the cooling pipe to compulsorily feed the cooling fluid in the cooling pipe when a temperature detected by the temperature sensor exceeds a specific level.

Also, according to another aspect of the present invention, there is provided an apparatus for collecting solar energy using a solar cell module for a roof, comprising: a conversion device electrically connected to a solar cell panel to convert electricity generated from the solar cell panel into a commercial electric power; a heat sink control part for driving the cooling means when a temperature sensed by the temperature sensor exceeds a specified temperature; and a heat recovery part for recovering heat energy from the cooling fluid of which the temperature has been heightened after cooling the solar cell panel.

Advantageous Effects

With the above description, the solar cell module for the roof and the solar energy collecting apparatus using the same are constituted to generate the electricity using the solar energy and to recover the radiant heat from the fluid used to cool the solar cells, which can improve the energy productivity.

In the solar cell module according to the present invention, if the temperature of the solar cell exceeds a specific level, the solar cell is compulsorily cooled. Consequently, the present invention maintains the solar cell at the optimum temperature to improve the efficiency of power generation and prevent deterioration of the solar cell, thereby improving the durability of the solar cell.

In addition, since the solar cell module according to the present invention is covered by a round lighting window with the Fresnel lens formed on the inner surface thereof, it can improve the power generating capability by condensing the sunlight onto the center portion of the module.

Since double condensers are disposed on the solar cell panel, the sunlight is condensed onto the solar cell panel at the center portion of the module to improve the power generating capability. Also, the expensive solar cell panel can be downsized to decrease the manufacturing cost thereof.

Brief Description of the Drawings

The foregoing and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view illustrating a front side of a conventional solar cell module;

FIG. 2 is a perspective view illustrating a rear side of the solar cell in Fig. 1;

FIG. 3 is a perspective view illustrating a solar cell module according to a first embodiment of the present invention;

FIG. 4 is a cross-sectional view taken along line A-A' in FIG. 3;

FIG. 5 is a perspective view illustrating a heat sink and a cooling pipe of the solar cell module in FIG. 3;

FIG. 6 is a perspective view illustrating a solar cell module according to the first embodiment of the present invention coupled to a roof panel;

FIG. 7 is a perspective view illustrating a solar cell module for a roof according to a second embodiment of the present invention;

FIG. 8 is a cross-sectional view taken along line B-B' in FIG. 7;

FIG. 9 is a perspective view illustrating a solar cell module for a roof according to a third embodiment of the present invention;

FIG. 10 is a cross-sectional view taken along line C-C' in FIG. 9;

FIG. 11 is a perspective view illustrating a solar cell module for a roof according to a fourth embodiment of the present invention;

FIG. 12 is a cross-sectional view taken along line D-D' in FIG. 11;

FIG. 13 is a perspective view illustrating a solar cell module for a roof according to a fifth embodiment of the present invention;

FIG. 14 is a cross-sectional view taken along line E-E' in FIG. 13;

FIG. 15 is a perspective view illustrating a solar cell module for a roof according to a sixth embodiment of the present invention;

FIG. 16 is a cross-sectional view taken along line F-F' in FIG. 15;

FIG. 17 is a perspective view illustrating components inside the solar cell module in FIG. 15;

FIG. 18 is a perspective view illustrating a lighting window of the solar cell module in FIG. 15;

FIG. 19 is a cross-sectional view taken along line G-G' in FIG. 18;

FIGs. 20 and 21 are schematic views illustrating a light condensing state when sunlight is incident on the solar cell module in FIG. 15;

FIG. 22 is a perspective view illustrating the solar cell module in FIG. 15 coupled to a roof panel; and

FIGs. 23 to 25 are schematic views illustrating various constructions of a solar energy collecting apparatus using a solar cell module according to the present invention.

Best Mode

Reference will now be made in detail to the preferred embodiments of the present invention. It is to be understood that the following examples are illustrative only and the present invention is not limited thereto.

Solar cell modules for a roof according to various embodiments of the present invention and a solar energy collecting apparatus using the same will be described with reference to the accompanying drawings, in which in the entire description of the present invention, the same drawing reference numerals are used for the same elements across various figures.

FIG. 3 is a perspective view illustrating a solar cell module according to a first embodiment of the present invention. FIG. 4 is a cross-sectional view taken along line A-A' in FIG. 3. FIG. 5 is a perspective view illustrating a heat sink and a cooling pipe of the solar cell module in FIG. 3. Referring to FIGs. 3 to 5, a solar cell module 100a includes a main body 110, a solar cell panel 120, a temperature sensor 180 and a cooling means. The solar cell module 100a may further include a heat sink 170, a receptacle 140, and a lighting window 140.

The main body 110 is mounted on a roof panel. Preferably, the main body 110 is fastened to a projection protruding upwardly from the roof panel. A flange 111 having a plurality of fastening holes 113 protrudes from a side of the body 110, in which fastening members (not shown), such as screws, penetrate the fastening holes 113, and then are fastened to the protrusion of the roof panel to secure the roof panel.

Preferably, an engaging groove 115 is formed on the bottom surface of the main body 110 in order to receive the protrusion of the roof panel (see FIG. 6), that is, a reinforcing rib 210, so that the main body 110 and the roof panel are engaged to each other in a miter joint. In particular, it is preferable that the engaging groove 115 is formed at a center portion of the bottom surface of the main body 110, so that the engaging groove 115 has a W-shaped bending portion. The main body 110 may be directly installed on the roof panel so that the main body is not spaced apart from the roof of a building with the roof panel. Since an additional beam structure is not necessary, an installation period and cost can be reduced. Also, since the module is closely contacted with the roof, it is possible to prevent damage of the main body due to natural disaster, such as typhoon, and improve the appearance of the building.

The a solar cell panel 120 is mounted on the upper portion of the body 110, as shown in FIG. 4, and is spaced apart from the bottom surface of the main body 110 at a certain distance. Preferably, an insulator material 160 is filled in an interior of the main body 110, i.e., in a space formed between the solar cell panel 120 and the bottom surface of the main body 110. It minimizes the conduction of the radiant heat from the bottom surface of the main body 110 and the roof panel to the solar cell panel 120, thereby preventing overheating of the solar cell panel 120.

A plurality of solar cells made of silicon semiconductor is arranged on the solar cell panel 120. When sunlight is incident onto the respective solar cells, the solar cell generates electricity using a photoelectric effect. The electricity generated by the solar cell panel 120 is output from a power output terminal 141 of the receptacle 140 provided on the side of the main body 110. The receptacle 140 will now be described hereinafter.

The temperature sensor 180 serves to measure the temperature of the solar cell panel 120. The temperature sensor 180 is installed on the solar cell panel 120. Preferably, the temperature sensor 180 is installed on a side portion or lower portion of the solar cell panel 120. In this instance, the temperature sensor 180 directly measures the temperature of the solar cell.

The heat sink 170 is installed on the lower portion of the solar cell panel 120 to come in contact with the solar cell panel 120 (for example, the heat sink is bonded to the solar cell panel 120 by an thermal adhesive), so that the heat sink 170 receives the heat from the solar cell panel 120. The heat sink 170 is maintained at the same temperature as that of the solar cell panel 120. The temperature of the solar cell panel is indirectly measured by installing the temperature sensor 180 on the heat sink 170. Consequently, the temperature sensor 180 may be installed on the side portion or lower portion of the solar cell panel 120 or the heat sink 170. In a case where the heat sink 170 is not provided, the temperature sensor 180 is installed on the side portion or lower portion of the solar cell panel 120.

The cooling means serves to cool the solar cell panel 120 by compulsorily feeding a cooling fluid between the solar cell panel 120 and the bottom surface of the main body 110 (if the heat sink is not provided) or the heat sink 170 and the bottom surface of the main body 110 (if the heat sink is provided). The cooling means cools the solar cell panel 120 by compulsorily feeding the cooling fluid if the temperature detected by the temperature sensor 180 is more than a preset temperature, thereby effectively preventing the overheating of the solar cell panel 120. An efficiency of power generation is increased when the temperature of the solar cell panel 120 is maintained in the range of 20℃ to 26℃, preferably 25℃. Preferably, the preset temperature to react the temperature sensor 180 is more than 26℃.

The cooling means is installed in such a manner that the cooling means comes in thermally contact with the solar cell panel 120 or the heat sink 170, as shown in FIGs. 3 to 5. The cooling means has a cooling pipe 150 through which the cooling fluid flows. The cooling fluid consists of a mixture mixed with a coolant and an antifreezer. In a case where there is no freezing, the cooling fluid may include only a coolant. As shown in FIGs. 4 and 5, the cooling pipe 150 is placed on the lower portion of the heat sink 170 in a thermally contact manner to perform heat exchange with the heat sink 170. In a case where the heat sink 170 is not provided, the cooling pipe 150 is placed on the lower portion of the solar cell panel 120 in a thermally contact manner to perform heat exchange with the solar cell panel 120.

Also, the cooling pipe 150 penetrates the space formed between the solar cell panel 120 or the heat sink 170 and the bottom surface of the main body 110. Preferably, an inlet port and an outlet port are formed on both sides of the main body 110. In this instance, its both ends, that is, the inlet port and the outlet port, are exposed outwardly from the both sides of the main body 110, as shown in FIG. 3. In particular, it is preferably that the inlet port and the outlet port of the cooling pipe 150 exposed from the main body 110 have different diameter.

For example, the inlet port of the cooling pipe 150 which is positioned at a lower portion when viewing the FIGs. 3 and 5 has a small diameter, while the outlet port of the cooling pipe 150 which is positioned at an upper portion when viewing FIGs. 3 and 5 has a large diameter. When two solar cell modules 100a are connected to each other in series, the cooling pipes 150 of the solar cell modules 100a are jointed to each other without using an additional connector. In this instance, a sealing (not shown) is interposed between the jointed portions of the two cooling pipes 150 in order to prevent leakage of the cooling fluid.

As shown in FIG. 5, the cooling pipe 150 and the heat sink 170 can be manufactured in modularization. By constituting the heat sinks 170 and the cooling pipes 150 in pair, a thickness of the main body 110 is thinned, and thus the radiant heat is quickly absorbed. The modularization can reduce the manufacturing cost and easily extend a width of the solar cell module 100a.

A pump 331 may be provided at the cooling means in order to compulsorily feed the cooling fluid in the cooling pipe 150. The pump 331 is communicated with the cooling pipe 150, and compulsorily feeds the cooling fluid in the cooling pipe 150 when the temperature of the solar cell panel 120 detected by the temperature sensor 180 is more than a preset temperature.

The receptacle 140 is installed on the side of the main body 110, as shown in FIG. 3, and is electrically connected with the solar cell panel 120 and the temperature sensor 180. The receptacle 140 includes an power output terminal 141 electrically connected to the solar cell panel 120 and a sensor output terminal 143 electrically connected to the temperature sensor 180. The receptacle 140 is respectively provided on both opposite sides of the main body 110 which is placed at a lower portion when viewing the drawing.

The receptacle 140 positioned at the lower portion is formed in a male type, while the receptacle 140 positioned at the upper portion is formed in a female type, and vice versa. Preferably, the receptacles 140 have a waterproof structure in order to improve the durability of the connection terminal when the receptacles are connected to each other.

With the construction of the receptacles 140, when two solar cell modules 100a are connected to each other in series, the receptacles 140 provided on the sides of the respective solar cell modules 100a are mechanically and electrically coupled to each other, without using additional connector. Therefore, the temperature sensors 180 and the solar cell panels 120 of two solar cell modules 100a which are placed adjacent to each other are electrically connected to each other. Also, if two modules are placed adjacent to each other, channels for heating or cooling the solar cell are automatically connected to each other. With the construction, the solar cell modules are easily installed, since it is not necessary to perform the connection operation additionally as the prior art.

When sunlight is incident onto the solar cell module 100a, the solar cells of the solar cell panel 120 generate the electricity using a photoelectric effect. The generated electricity is output from the power output terminal 141 of the receptacle 140. When the solar cell panel 120 is heated by the sunlight, the heat generated from the solar cell panel 120 is conducted to the cooling pipe 150 through the heat sink 170.

Also, if the temperature of the solar cell panel 120 is raised above a certain temperature, the cooling means is driven to feed the cooling fluid in the cooling pipe 150. Thus, the cooling of the heat sink 170 and the solar cell panel 120 is accelerated to prevent the overheating and deterioration of the solar cell panel 120. Consequently, the solar cell panel 120 generates the electricity at a high efficiency at an optimum temperature (about 25℃).

The cooling fluid heat-exchanged and heated by the cooling pipe will be used for hot water supply or heating, which will be described hereinafter.

The flat lighting window 130 is substantially identical to a lighting window provided on a conventional solar cell panel, its detailed description being omitted herein.

FIG. 6 is a perspective view illustrating the solar cell module according to the first embodiment of the present invention coupled to the roof panel. The solar cell module 100 is directly mounted on the roof panel 200 of a building. In general, the roof panel 200 is made by filling an insulator 230 such as urethane between steel plates, and a plurality of reinforcing ribs 210 protrude from the upper surface 220 of the roof panel to reinforce its strength. In order to mount the main body 110 onto the roof panel, the reinforcing rib 210 is inserted in the engaging groove 115 of the main body 110, and then the flange 111 is laid on the upper end of the reinforcing rib 210. The flange 210 is secured to the roof panel 200 by fastening waterproof fastening members 119 to the fastening holes 113 of the flange 111, so that the solar cell module 100 is stably and firmly mounted on the roof panel. The solar cell modules 100 are arranged in series in such a manner that the receptacles 140 are connected to each other. In this instance, the cooling pipes 150 are connected to each other (see FIG. 23).

Although not shown in the drawings, the reinforcing ribs 210 are not provided on the roof panel of the building on which the solar cell module 100 is installed, that is, the upper surface of the roof panel is flat, long reinforcing frames are securely placed on the upper surface of the roof panel at a certain interval to form a protrusion, so that the main body 110 is secured by using the reinforcing frames serving as the protrusion. The solar cell module 100 is not spaced apart from the roof, it does not destroy the appearance of the building and does not cause the strength to be weaken.

FIG. 7 is a perspective view illustrating a solar cell module for a roof according to a second embodiment of the present invention, and FIG. 8 is a cross-sectional view taken along line B-B' in FIG. 7. As shown in FIGs. 7 and 8, a solar cell module 100b for a roof includes a main body 110, a solar cell panel 120, a temperature sensor 180 and a cooling means. The solar cell module 100b may further include a heat sink 170 and a receptacle 140.

The solar cell module for the roof according to the second embodiment of the present invention is similar to that according to the first embodiment, except for the cooling means. More specifically, the cooling means according to the first embodiment is formed in a water-cooled type, while the cooling means according to the second embodiment is formed in an air-cooled type.

Therefore, the cooling means of the solar cell module 100b according to the second embodiment of the present invention will now be described, and the descriptions of the solar cell panel 120, the temperature sensor 180, the heat sink 170, the receptacle 140 and the lighting window which are substantially similar to those of the first embodiment will be omitted.

The cooling means includes a ventilation channel 151 and cooling fins 171, as shown in FIGs. 7 and 8. The ventilation channel 151 is ensured by a space formed between the bottom surface of the main body 110 and the solar cell panel 120 or the heat sink 170. To this end, an insulator is not filled in the empty space of the main body 110. The ventilation channel 151 has an inlet port and an outlet port at both sides of the main body 110, so that external air passes through the ventilation channel 151.

The ventilation channel 151 minimizes the heat conduction from the roof panel and the bottom surface of the main body 110 to the solar cell panel 120. Also, the cool air passing through the ventilation channel 151 cools the solar cell panel 120 and the heat sink 170 to effectively prevent the overheating of the solar cell panel 120.

The cooling fins 171 are to increase an efficiency of heat radiation of the solar cell panel 120 or the heat sink 170. As shown in FIGs. 7 and 8, the cooling fins are extended downwardly from the solar cell panels 120. In a case where the heat sink 170 is provided, a plurality of cooling fins 171 are extended downwardly from the heat sink 170, and the cooling fins 171 extended from the solar cell panel 120 or the heat sink 170 are disposed in the ventilation channel 151. Consequently, the heat of the solar cell panel 120 is heat-exchanged with the cool air passing through the ventilation channel 151 by the cooling fins 171 at a wide area. Since the solar cell panel 120 is quickly cooled, it can effectively prevent the overheating and deterioration of the solar cell panel 120.

Also, the cooling means may include a blower 335 (see FIG. 24). The blower 335 is communicated with the ventilation channel 151 to compulsively circulate the air in the ventilation channel 151 when the temperature of the solar cell panel 120 detected by the temperature sensor 180 is more than a preset level. Consequently, it can effectively prevent the efficiency of power generation of the solar cells from being deteriorated due to the overheating of the solar cell panel 120, thereby preventing the deterioration of the solar cell panel 120.

The selection of the cooling means of water-cooled type (the first embodiment) or air-cooled type (the second embodiment) for cooling the solar cell panel 120 is depended upon the climate and solar radiation of an area in which the solar cell modules 100a and 100b according to the present invention are installed. In this instance, it is preferable to consider the heat recovery and use of the cooling fluid heated by the solar cell panel 120 and the usage thereof.

FIG. 9 is a perspective view illustrating a solar cell module for a roof according to a third embodiment of the present invention, and FIG. 10 is a cross-sectional view taken along line C-C' in FIG. 9. As shown in FIGs. 9 and 10, a solar cell module 100c for a roof according to the third embodiment of the present invention is substantially identical to that according to the second embodiment of the present invention, except for that the solar cell panel 120 is disposed at a certain slope to the bottom surface of the main body 110.

More specifically, in the solar cell module for the roof according to the second embodiment of the present invention, the solar cell panel 120 is placed in parallel with the bottom surface of the main body 110. In this instance, when the solar cell module 100b is installed on the roof, the solar cell panel 120 is placed at the same slope as that of the roof. In general, the most preferable installation direction of the solar cell module is a full south aspect in which the solar radiation is the maximum. If the roof of the building does not have the full south aspect, the solar radiation of the solar cell panel 120 is decreased, and thus the power generation capacity is deteriorated.

In order to install the solar cell module on the building having other aspects except for the full south aspect, the solar cell module is generally mounted on a beam structure protruding from the roof. Such a mounting structure has drawbacks of destructing the appearance of the building and being weak to a natural disaster such as strong wind.

The solar cell module 100c according to the third embodiment of the present invention can solve the above drawbacks. As shown in FIGs. 9 and 10, the solar cell panel 120 of the solar cell module 100c according to the third embodiment of the present invention is placed at a certain slope to the bottom surface of the main body 110 in a certain direction. More specifically, a slope support 117 is provided on the upper portion of the main body 110 to raise one side of the solar cell panel 120, so that the solar cell panel 120 is supported by the slope support 117. Thus, the solar cell panel 120 is disposed at a certain slope to a horizontal surface. Since the solar cell modules 100c is substantially identical to the solar cell modules 100a and 100b according to the first and second embodiments of the present invention, except for the slope support 117 for supporting the solar cell panel 120 at a certain slope, the detailed description thereof will now be omitted herein.

The solar cell module 100c having the inclined solar cell panel 120 can be disposed at a certain slope different from a slope of the roof when it is installed on the roof of the building. If the inclined direction and slope of the solar cell panel 120 are properly selected, the solar cell module 100c can be installed so that the solar cell panel 120 is disposed in a full south aspect. The installed solar cell module 100c is harmonized with the building. Also, it is little affected by a strong wind and minimizes total reflection of the sunlight to increase the solar radiation and thus maximize the efficiency of power generation.

Since the slope of the solar cell panel 120 is increased due to the slope (about 10° to 30°) of the roof panel of a building and an inherent slope (about 15° to 45° in one direction) of the solar cell panel 120, dust or snow is hardly accumulated on the solar cell panel 120, and the accumulated dust or snow can be easily washed by rain or wind. Consequently, contamination of the solar cell panel 120 is decreased to improve the efficiency of power generation.

FIG. 11 is a perspective view illustrating a solar cell module for a roof according to a fourth embodiment of the present invention, and FIG. 12 is a cross-sectional view taken along line D-D' in FIG. 11. FIG. 13 is a perspective view illustrating a solar cell module for a roof according to a fifth embodiment of the present invention, and FIG. 14 is a cross-sectional view taken along line E-E' in FIG. 13. FIG. 15 is a perspective view illustrating a solar cell module for a roof according to a sixth embodiment of the present invention, and FIG. 16 is a cross-sectional view taken along line F-F' in FIG. 15. FIG. 17 is a perspective view illustrating components inside the solar cell module in FIG. 15. FIG. 18 is a perspective view illustrating a lighting window of the solar cell module in FIG. 15, and FIG. 19 is a cross-sectional view taken along line G-G' in FIG. 18. FIGs. 20 and 21 are schematic views illustrating a light condensing state when sunlight is incident on the solar cell module in FIG. 15.

As shown in FIGs. 11 to 21, solar cell modules 100d, 100e and 100f for a roof according to the fourth to sixth embodiments of the present invention have an improved construction to protect the solar cell panel 120, prevent contamination, and increase an amount of light coupled into solar cells. Unlike the solar cell module for the roof according to the first to third embodiments of the present invention, round lighting windows 190a and 190b are installed on the upper portion of the main body in order to close and seal the solar cell panel 120.

The round lighting window 190a can be applied to the solar cell modules 100a, 100b and 100c according to the first to third embodiments of the present invention. Since the solar cell module according to the fourth embodiment of the present invention is substantially identical to those according to the first to third embodiments of the present invention, except for the round lighting window 190a, its description will be omitted, but the round lighting window 190a will now be described herein.

As shown in FIGs. 11 and 12, the lighting window 190a is made by bending and shaping a low-iron tempered glass in an oval shape when viewing at a side and attaching a flat glass to both sides and lower end of the shaped tempered glass. Of course, the lighting window 190a has an opened lower portion. Since the lighting window 190a is formed in a round construction, it resists external shock such as large hailstones, as compared with a flat lighting window. Also, since it is possible to make the lighting window in a thin thickness, the lighting window can be lightened.

The round lighting window 190a is installed on the upper portion of the main body to be positioned over the solar cell panel 120. The solar cell panel 120 is closed and sealed, thereby preventing the solar cell panel 120 from coming in contact with the exterior. Since the round lighting window 190a has a round external surface, dust or snow is hardly accumulated on the round lighting window 190a, and the accumulated dust or snow can be easily washed by rain or wind. Consequently, the round lighting window 190a can prevent contamination of the solar cell panel 120 and prevent the light receiving capability and the efficiency of power generation from being deteriorated, as compared with a general flat lighting window 130 closing the solar cell panel 120. The solar cell module 100d according to the fourth embodiment of the present invention is suitable to ensure a sufficient solar radiation in areas suffering from yellow sand, atmosphere contamination or deep snow.

Referring to FIGs. 13 to 21, solar cell modules 100e and 100f according to the fifth and sixth embodiments of the present invention are provided with a function of condensing the sunlight on the solar cell panel 120 to increase the solar radiation. More specifically, the lighting windows 190b of the solar cell modules 100e and 100f are formed in a semi-cylindrical shape in order to effectively condense the sunlight on the solar cell panels 120 disposed at a center portion of the solar cell module. In this instance, the solar cell panel 120 is disposed at the upper center portion of the main body 110, and a Fresnel lens pattern is formed on an inner surface 191 of the lighting window 190b to refract the sunlight. The Fresnel lens is a lens that a surface of the lens is machined in multiple segments to reduce a thickness of the lens, and each segment has a prism function to decrease aberration. The fifth embodiment of the present invention is substantially identical to the sixth embodiment of the present invention, except for an engaging groove 115 formed on the bottom surface of the main body 110.

The inner surface 191 of the semi-cylindrical lighting window 190b is machined in a stepped shape to form multiple segments, as shown in FIGs. 13 to 16. The light passing through the lighting window 190b is refracted by the machined inner surface 191, and then is focused on the upper center portion of the main body 110. A part of the sunlight reflected from the surface of the solar cell panel 120 is reflected by the inner surface 191 of the lighting window 190b, and then is again incident on the solar cell panel 120. with the above construction, the efficiency of power generation of the solar cell panel 120 is improved.

Since the lighting window with the Fresnel lens pattern condenses the incident sunlight on the upper center portion of the main body 110, a size of the solar cell panel 120 can be reduced, as shown in FIGs. 13 to 16. More specifically, even though the solar cell panel 120 is disposed on the upper center portion of the main body 110, the power generating capability is improved by the lighting window 190b with the Fresnel lens pattern having the function of condensing and reflecting the light. Consequently, it is possible to reduce an amount of the expensive solar cells by downsizing the solar cell panel 120.

In addition, by installing reflectors 195 on both sides of the downsized solar cell panels 120, as shown in FIGs. 13 to 16, the power generating capability of the solar cell panel 120 is further improved. Specifically, the sunlight, that passes through the semi-cylindrical lighting window 190b or is reflected by the inner surface 191 of the lighting window 190b and then is incident on a position slightly deviated from the solar cell panel 120, is reflected by the reflector 195 and the inner surface 191 of the lighting window 190b, and then is incident on the solar cell panel 120, thereby improving the power generating capability of the solar cell panel 120.

More specifically, it is preferably that the reflector 195 is disposed at a certain slope in such a manner that one portion of the reflector 195 adjacent to the solar cell panel 120 is placed at a position lower than the other portion far away from the reflector 195. The reflector 195 reflects the sunlight that is incident around the solar cell panel 120 through the lighting window 190b, to the inner surface 191 of the lighting window 190b. The light reflected from the reflector 195 is again reflected by the inner surface 191 of the lighting window 190b, and then is incident on the solar cell panel 120.

Preferably, the reflector 195 is made of a material having high reflectivity and thermal conductivity.

Preferably, the reflector 195 is formed in a wedge shape, as shown in FIG. 16, so that the portion of the reflector 195 contacting the heat sink 170 has a thickness thicker than the portion far away from the heat sink 170. With the construction, a contact area of the reflector 195 and the heat sink 170 is enlarged to quickly conduct the heat absorbed by the reflector 195 to the heat sink 170.

The lighting window 190b includes, as shown in FIGs. 18 to 19, in particular, FIGs. 18 and 19, a first condenser 192 and a second condenser 193, in order to improve an efficiency of condensing the light on the solar cell panel 120. The first condenser 192 is installed on the upper portion of the main body 110, and has an area wider than that of the solar cell panel 120. A Fresnel lens pattern is formed on the inner surface of the first condenser 192 to refract the light. The second condenser 193 is installed in the inside of the first condenser 192 to cover the solar cell panel 120, and a convex lens is formed on the inner surface of the second condenser 193 to refract the light.

With the above construction, the light passing through the first condenser 192 is refracted towards the inside to condense the light towards the solar cell panel 120. Further, the light reflected by the reflector 195 is reflected by the machined inner surface 120, and then is incident on the solar cell panel 120. Therefore, it increases an incident rate of the sunlight towards the solar cell panel 120.

The second condenser 193 has a flat bottom surface, and a top surface formed in a planoconvex lens, in which the flat bottom surface is disposed on the solar cell panel 120. The second condenser 193 secondarily condenses the sunlight refracted by the first condenser 192, or condenses the reflected light onto the solar cell panel 120, thereby further improving the incident rate of the sunlight towards the solar cell panel 120.

The first condenser 192 may be formed in an integral condenser by machining or forming the inner surface of one semi-cylindrical body. As shown in FIG. 19, after flat surfaces of multiple planoconvex lenses a, b and c are cut, the lenses are coupled to each other so that the cut surfaces face towards the inside to form one semi-cylindrical condenser.

Preferably, the space formed between the first condenser 192 and the second condenser 193 is sealed, and the sealed space is maintained in a substantial vacuum state. The expression 'vacuum' or 'substantial vacuum' means a full or almost vacuum state. More specifically, a lateral plate 196 is provided on the side of the lighting window 190b, as shown in FIG. 19. The lateral plate 196 connects the lateral end of the first condenser 192 with the lateral end of the second condenser 193 to seal the side of the lighting window 190b. A bottom plate 194 is disposed under the lighting window 190b to connect the lower end of the first condenser 192 with both ends of the second condenser 193 and thus seal the lower portion of the lighting window 190b. The lighting window 190b is completely sealed, and the interior thereof forms a substantial vacuum. Consequently, the interior of the lighting window 190b is not contaminated to sufficiently secure an amount of the light incident on the solar cell panel 120, although it is used for a long time.

The operation of condensing the sunlight on the solar cell panel 120 will now be described with reference to FIGs. 20 and 21.

As shown in FIG. 20, if the sunlight is vertically incident on the solar cell module 100, the sunlight entering onto the center portion of the first condenser 192 is primarily refracted at the center portion of the first condenser 192, and then is condensed on the second condenser 193. The sunlight entering onto the second condenser 193 is finely refracted and condensed on the solar cell panel 120.

After the sunlight entering onto the left and right sides of the first condenser 192 is refracted at the sides of the first condenser 192, and then a part of the refracted sunlight enters onto the second condenser 193, and the remainder irradiates on the reflector 195. The sunlight irradiating on the reflector 195 is reflected by the reflector 195, and then is reflected by the inner surface 195 of the first condenser 192. The light reflected by the inner surface of the first condenser

192 at an incidence angle which is within a critical angle enters onto the second condenser 193. Consequently, a lot of sunlight and reflected light enter the solar cell panel 120 through the solar cell panel 120, thereby improving the efficiency of the power generation of the solar cell panel 120.

As shown in FIG. 21, if the sunlight enters onto the solar cell module 100 at a slope, the sunlight incident on the side of the first condenser 192 at a slope is refracted by the first condenser 192. A part of the sunlight enters onto the second condenser 193, and then enters onto the solar cell panel 120, while the remainder enters onto the reflector 195. After the sunlight entering on the reflector 195 is reflected, it directly enters onto the second condenser 193, or is reflected by the inner surface 191 of the first condenser 192 which is positioned opposite to a position on which the sunlight is reflected, and then enters onto the second condenser 193. Since the sidelight of sun direction and the reflected light opposite to the sun direction are evenly incident on the solar cell panel 120, the power generation of the solar cell panel 120 can be stably obtained, irregardless of position change of the sun.

In a case where it is installed on the roof having a full south aspect to obtain sufficient solar radiation or the sun is positioned at meridian altitude, the sunlight enters onto the solar cell panel 120, as described above with reference to FIG. 20, to improve the capability to convert the electricity in the solar cell modules 100e and 100f. In a case where it is not installed in the full south aspect or it is by the morning or evening, the incidence amount of the sunlight is remarkably reduced. However, the solar cell modules 100e and 100f reflects the sidelight in the lighting window 190b several times to condense it onto the solar cell panel 120, thereby improving the capability to convert the electricity.

FIG. 22 is a perspective view illustrating the solar cell module in FIG. 15 coupled to the roof panel. The solar cell module according to this embodiment is substantially identical to the fifth embodiment of the present invention, except for that the engaging groove 115 is formed on the bottom surface of the main body 110. Since the construction, in that after the flange 111 of the main body 110 is laid on the upper end of the reinforcing rib 210 of the roof panel, the flange 210 is secured to the roof panel 200 by fastening waterproof fastening members 119 to the fastening holes 113 of the flange 111, and in that the cooling pipe 150 is connected to the receptacle 140, is similar to each other, its detailed description will be omitted herein.

FIGs. 23 to 25 are schematic views illustrating various constructions of a solar energy collecting apparatus using the solar cell module according to the present invention. FIGs. 23 and 25 show solar energy collecting apparatuses using the water-cooled solar cell modules 100a and 100f, and FIG. 24 shows a solar energy collecting apparatus using the air-cooled solar cell module 100b.

The solar energy collecting apparatus using the water-cooled solar cell module includes, as shown in FIGs 23 and 25, an electricity conversion device 310, heat sink control parts 320 and 330, and heat recovery parts 332, 340 and 350. The solar energy collecting apparatus shown in FIG. 23 is substantially identical to that shown in FIG. 25, except for the lighting window of the solar cell module, i.e., the flat lighting window and the round lighting window.

The electricity conversion device 310 is electrically connected to the solar cell panel 120 to convert the electricity generated from the solar cell panel 120 into a commercial electric power. The heat sink control part drives the cooling means when a temperature sensed by the temperature sensor 180 exceeds a specified temperature.

The heat sink control part includes, as shown in FIG. 23, a temperature detecting part 320 connected to the temperature sensor 180, and a heat exchange control part 330 electrically connected to the temperature detecting part 320 and the pump 331 to drive the pump 331 when the detected temperature exceeds a specified temperature. If the pump 331 is driven by the heat exchange control part 330, the cooling fluid is compulsorily fed through the pipe line 155 and the cooling pipe 150. Consequently, the solar cell panel 120 is cooled to prevent the overheating and deterioration of the solar cell panel 120 and thus improve the durability.

The heat recovery part includes a cooling fluid tank 340 storing the cooling fluid, a hot water tank 350 connected to the cooling fluid tank 340, and a pump 332 interposed between the cooling fluid tank 340 and the hot water tank 350. The cooling fluid stored in the cooling fluid tank 340 is fed by the pump 331 to cool the solar cell panel 120, and then is recovered to the cooling fluid tank 340 after its temperature is raised. Accordingly, the temperature of the cooling fluid stored in the cooling fluid tank 340 is gradually raised. The heat of the hot cooling fluid may be used for heating, but is heat-exchanged with the hot water tank 350. To this end, the cooling fluid tank 340 is provided with a heat exchanger (not shown) for heat-exchanging the water stored in the hot water tank 350 with the cooling fluid stored in the cooling fluid tank 340. The pump 332 circulates the hot water through the hot water tank and the heat exchanger. Consequently, the hot water stored in the hot water tank 350 is heated, and the hot water is used for the heating or the hot water supply. In a case where the cooling fluid stored in the cooling fluid tank 340 is directly used for the heating, the pump 332 and the hot water tank 350 may be omitted.

The solar energy collecting apparatus shown in FIG. 24 is installed in an area that is not suitable to the water-cooled manner, and includes an electricity conversion device 310, heat sink control parts 320 and 330, and a heat recovery part 360. Since the electricity conversion device 310 is identical to that shown in FIG. 23, its description will be omitted.

The heat sink control part includes a temperature detecting part 320 and a heat exchange control part 330, in which the functions thereof are identical to those described with reference to FIG. 23. However, the heat exchange control part 330 according to the embodiment of the present invention shown in FIG. 24 controls the operation of the blower 335 installed in a ventilation duct 157 which is connected to the ventilation channel 151. If the temperature of the solar cell panel 120 exceeds a specified temperature, the blower 335 is driven under the control of the heat exchange control part 330, so that the cooling air is fed in the ventilation channel 151 to cool the solar cell panel 120.

The hot air heated by the solar cell panel 120 may be discharge outwardly, or may be recovered by the heat recovery part 360, as shown in FIG. 24. The heat recovery part 360 may be a tank for storing the hot air, a heat exchanger for performing heat exchange with the hot air, or a combination thereof. That is, the heat recovery part 360 recovers the heat from the air heated by the solar cell panel 120, and uses the heat for the purpose of the heating or drying.

As described above, the solar cell module 100 for the roof and the solar energy collecting apparatus using the same are constituted to generate the electricity using the solar energy and to recover the radiant heat from the fluid used to cool the solar cells, which can improve the energy productivity.

In the solar cell module according to the present invention, if the temperature of the solar cell exceeds a specific level, the solar cell is compulsorily cooled.

Consequently, the present invention maintains the solar cell at the optimum temperature to improve the efficiency of power generation and prevent deterioration of the solar cell, thereby improving the durability of the solar cell.

In addition, since the solar cell module according to the present invention is covered by a round lighting window with the Fresnel lens formed on the inner surface thereof, it can improve the power generating capability by condensing the sunlight onto the center portion of the module.

Since double condensers are disposed on the solar cell panel, the sunlight is condensed onto the solar cell panel at the center portion of the module to improve the power generating capability. Also, the expensive solar cell panel can be downsized to decrease the manufacturing cost thereof.

Industrial Applicability

As can be seen from the foregoing, since the solar cell module for the roof according to the present invention improves the power generating capability and the durability, it can contribute to the industry of solar energy as a clean energy source.

While this invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiment and the drawings. On the contrary, it is intended to cover various modifications and variations within the spirit and scope of the appended claims.

Claims

1. A solar cell module for a roof, comprising:

a main body mounted on a roof panel;

a solar cell panel arranged apart from a bottom surface of the main body;

a temperature sensor installed on the solar cell panel to measure a temperature thereof; and

cooling means for cooling the solar cell panel by compulsorily making cooling fluid flow between the solar cell panel and the bottom surface of the main body.

2. The solar cell module as claimed in claim 1, wherein an engaging groove is formed on the bottom surface of the main body to receive a protrusion of the roof panel, and the solar cell panel is disposed at a certain slope to the bottom surface of the main body in one direction.

3. The solar cell module as claimed in claim 1, wherein an insulator material is filled in an interior of the main body to prevent radiant heat from being conducted to the solar cell panel from the bottom surface of the main body and the roof panel.

4. The solar cell module as claimed in claim 1, wherein a heat sink is installed on a power portion of the solar cell panel to come in contact with the solar cell panel, so that the heat sink receives the heat from the solar cell panel, and a temperature sensor is installed on a side portion or lower portion of the solar cell panel or the heat sin.

5. The solar cell module as claimed in claim 4, wherein the cooling means is installed in such a manner that the cooling means comes in thermally contact with the heat sink, and has a cooling pipe through which a cooling fluid flows, an inlet port and an outlet port being formed on both sides of the main body.

6. The solar cell module as claimed in claim 5, wherein the cooling means includes a pump communicated with the cooling pipe to compulsorily feed the cooling fluid in the cooling pipe when a temperature detected by the temperature sensor exceeds a specific level.

7. The solar cell module as claimed in claim 4, wherein the cooling means includes a ventilation channel interposed between the bottom surface of the main body and the heat sink and having an inlet port and an outlet port at both sides of the main body.

8. The solar cell module as claimed in claim 7, wherein the cooling means further includes a plurality of cooling fins extended downwardly from the heat sink and disposed over the ventilation channel.

9. The solar cell module as claimed in claim 8, wherein the cooling means further includes a blower communicated with the ventilation channel to compulsively circulate air in the ventilation channel when a temperature of the solar cell panel detected by the temperature sensor exceeds a specific level.

10. The solar cell module as claimed in claim 1, further comprising a

receptacle installed on a side of the main body and electrically connected with the solar cell panel and the temperature sensor, and wherein when two or more solar cell modules are disposed adjacent to each other, the receptacle electrically connects the solar cell panel and a temperature sensor of each solar cell module.

11. The solar cell module as claimed in claim 1, further comprising a round lighting window installed on an upper portion of the main body to close and seal the solar cell panel.

12. The solar cell module as claimed in claim 11, wherein a Fresnel lens pattern is formed on an inner surface of the lighting window to refract sunlight, the solar cell panel is positioned on an upper center portion of the main body, and reflectors are on both sides of the solar cell panel to reflect the sunlight entering around the solar cell panel towards the inner surface of the lighting window.

13. The solar cell module as claimed in claim 12, wherein the lighting window includes a first condenser and a second condenser, in which the first condenser is installed on the upper portion of the main body, and has an area wider than that of the solar cell panel, a Fresnel lens pattern being formed on an inner surface of the first condenser, and the second condenser is installed in the first condenser to cover the solar cell panel, a convex lens being formed on an inner surface of the second condenser, and wherein the sunlight reflected by the reflector towards the inner surface of the first condenser is again reflected by the inner surface of the first condenser, is refracted by the second condenser, and is condensed onto the solar cell panel.

14. The solar cell module as claimed in claim 13, further comprising a heat sink installed on a power portion of the solar cell panel to come in contact with the solar cell panel, and a temperature sensor installed on a side portion or lower portion of the solar cell panel or the heat sin, wherein the cooling means includes a pump communicated with the cooling pipe to compulsorily feed the cooling fluid in the cooling pipe when a temperature detected by the temperature sensor exceeds a specific level.

15. An apparatus for collecting solar energy using a solar cell module for a roof recited in any one of claims 1 to 14, comprising:

a conversion device electrically connected to a solar cell panel to convert electricity generated from the solar cell panel into a commercial electric power;

a heat sink control part for driving the cooling means when a temperature sensed by the temperature sensor exceeds a specified temperature; and

a heat recovery part for recovering heat energy from the cooling fluid of which the temperature has been heightened after cooling the solar cell panel.

Fig. 1

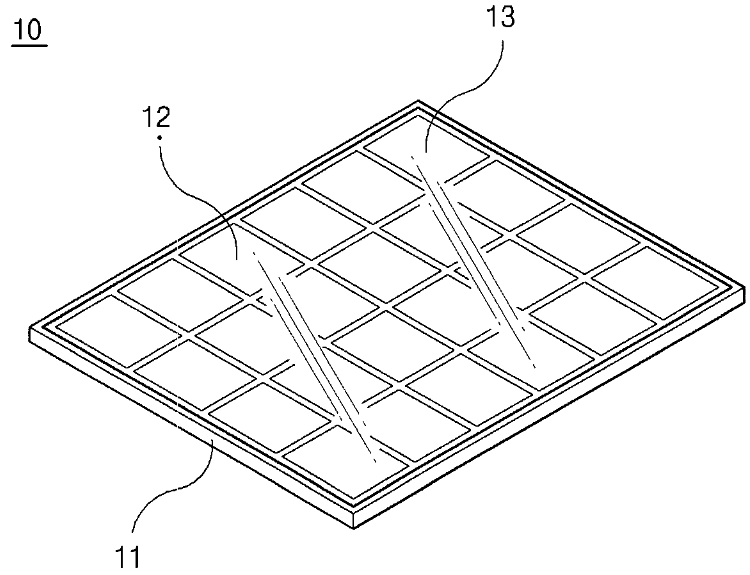


Fig. 2

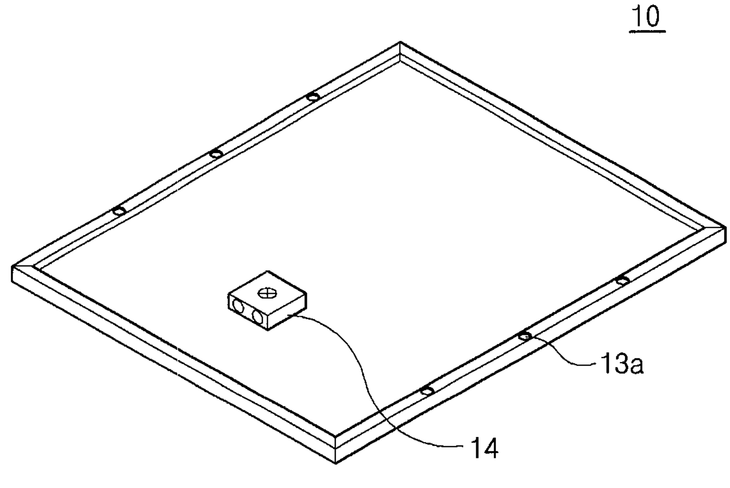


Fig. 3

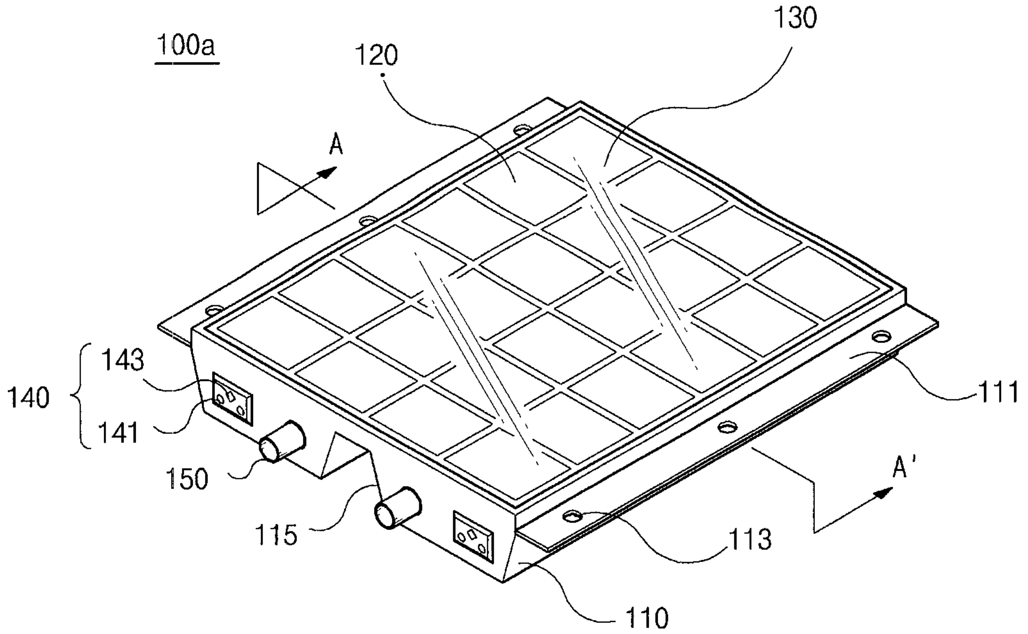
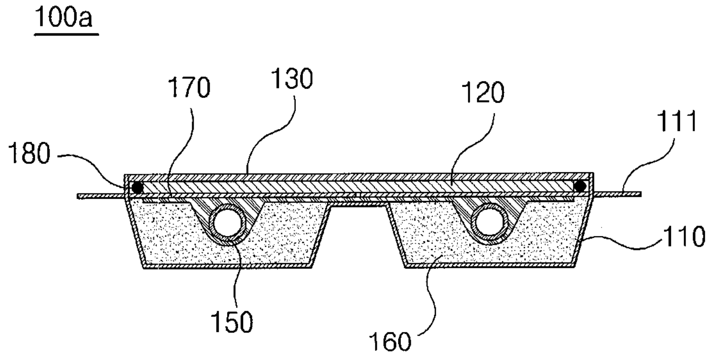

100a
130
120
A
143
140
141
150
115
111
A'
113
110

Fig. 4


100a
170
130
120
111
180
110
150
160

A - A'

Fig. 5

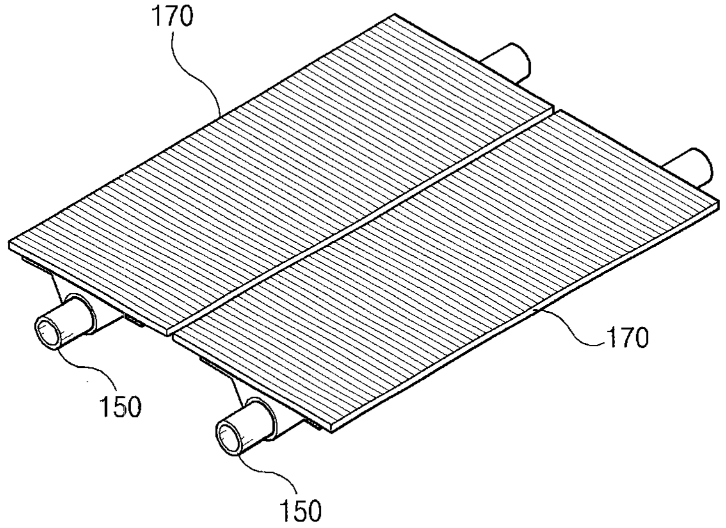


Fig. 6

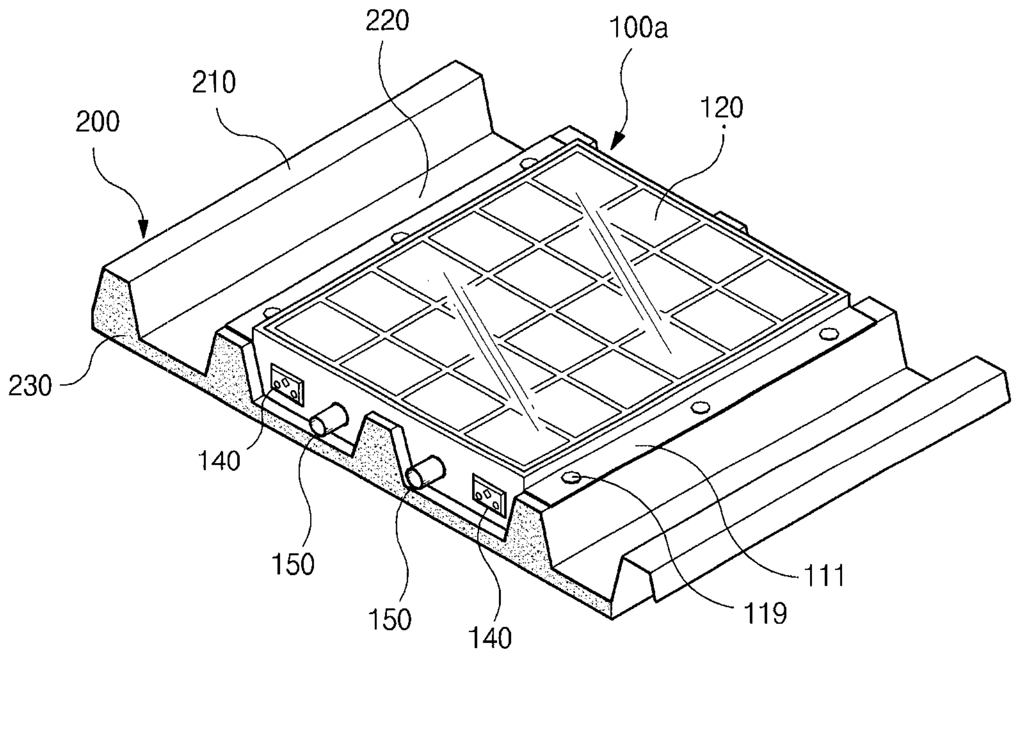


Fig. 7

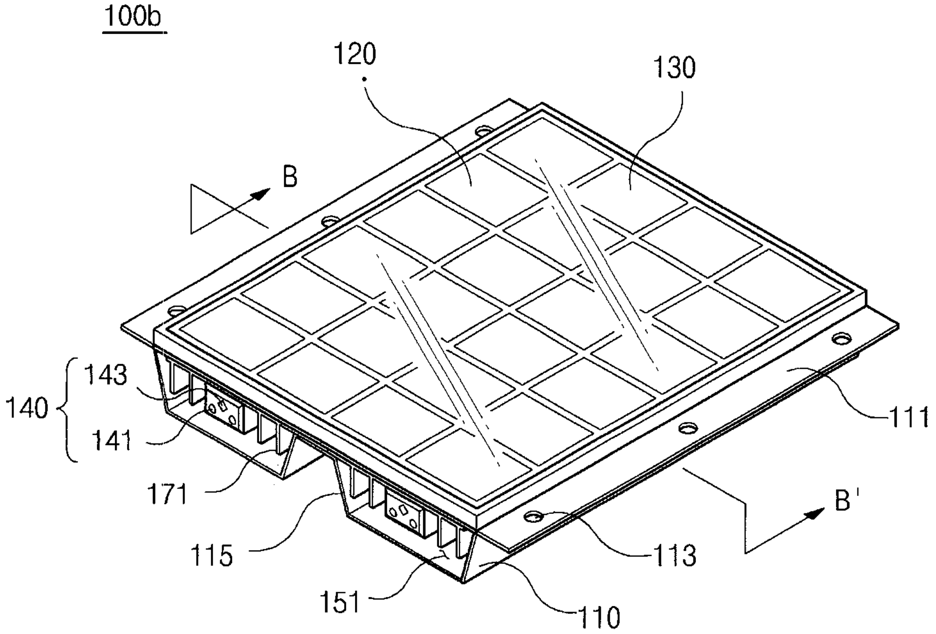

100b
120
130
B
143
140
141
171
111
B'
115
113
151
110

Fig. 8

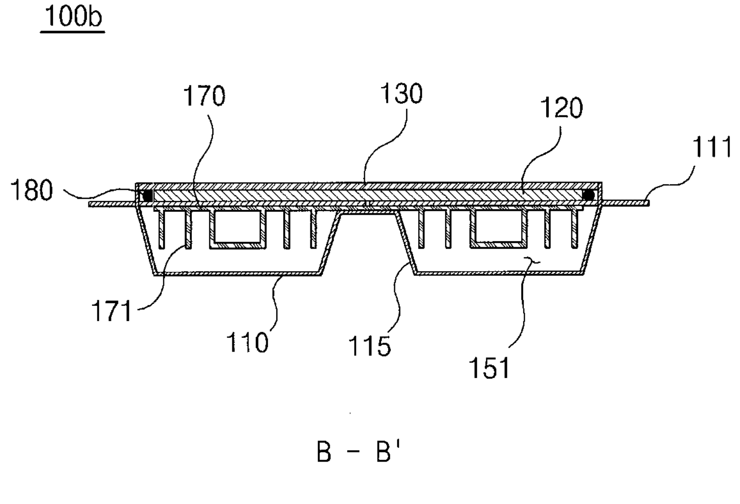

100b
170
130
120
111
180
171
110
115
151
B - B'

Fig. 9

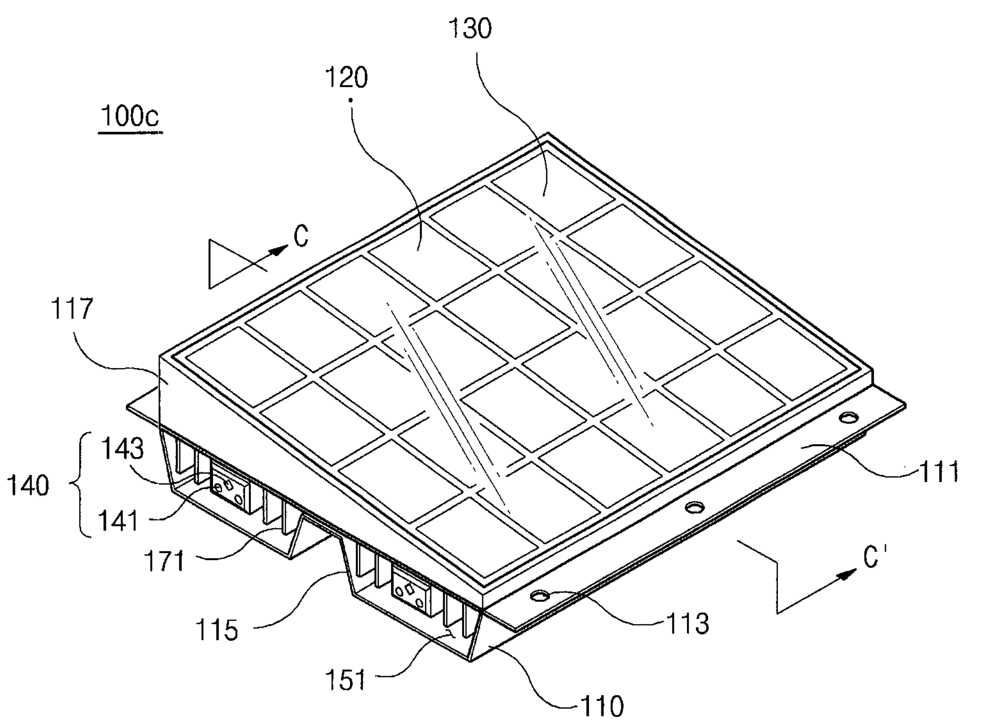
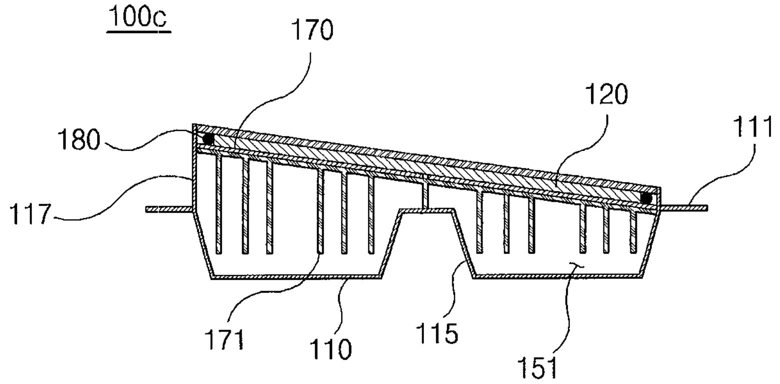


Fig. 10



C - C'

Fig. 11

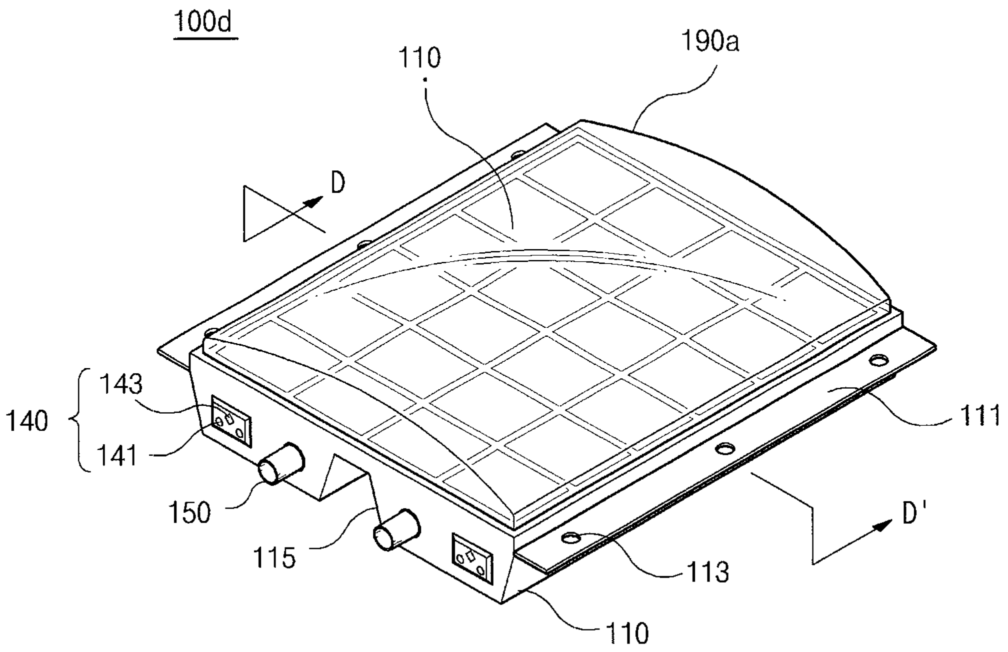
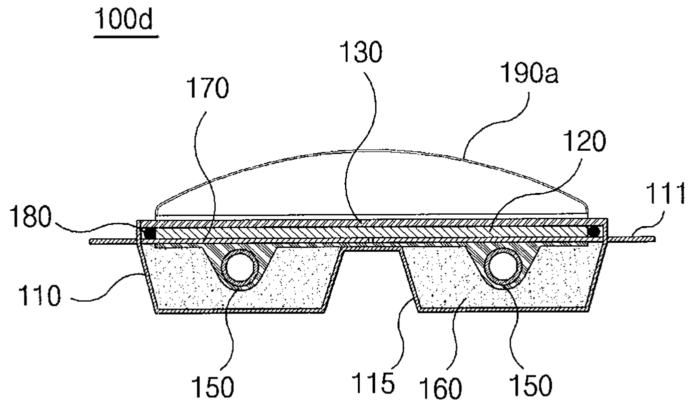


Fig. 12



D - D'

Fig. 13

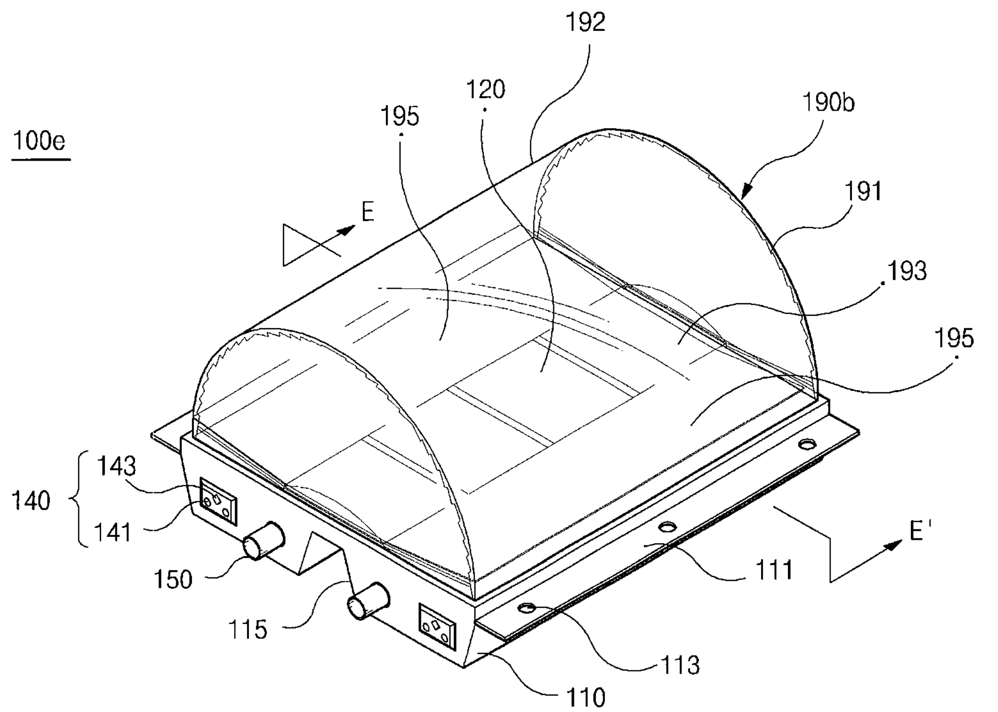

100e
192
120
195
190b
191
E
193
195
143
140
141
150
115
111
E'
113
110

Fig. 14

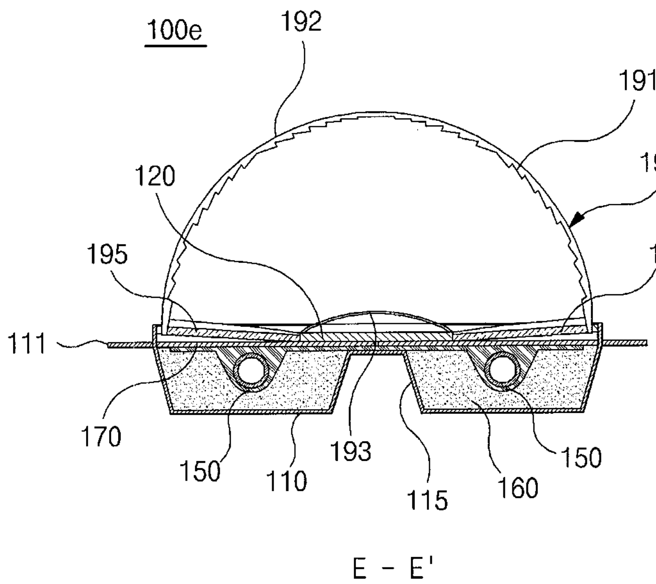

100e
192
191
190b
120
195
195
111
170
150
110
193
115
160
150
E - E'

Fig. 15

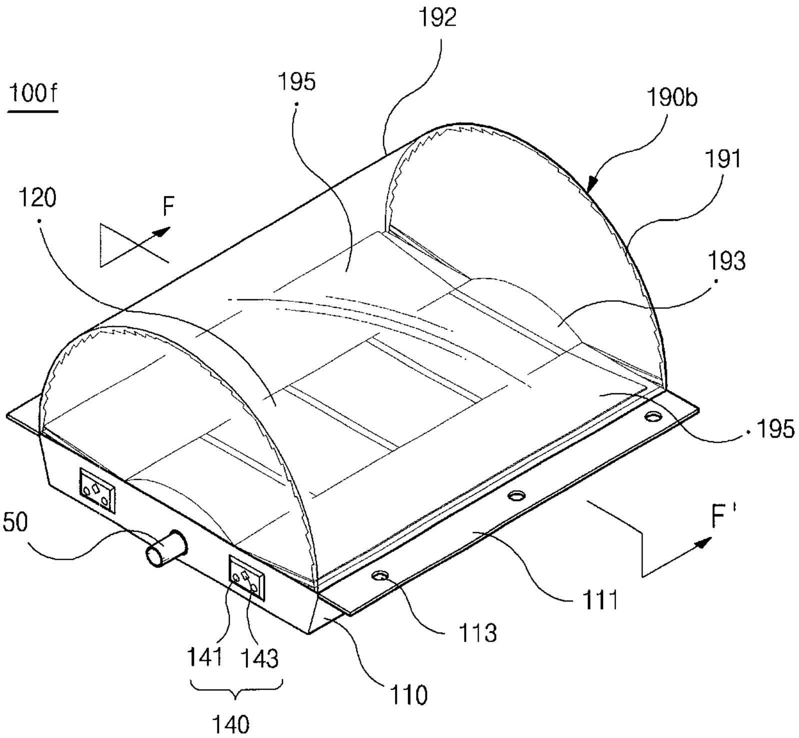

100f
192
195
190b
191
120
F
193
195
150
F'
111
113
141
143
140
110

Fig. 16

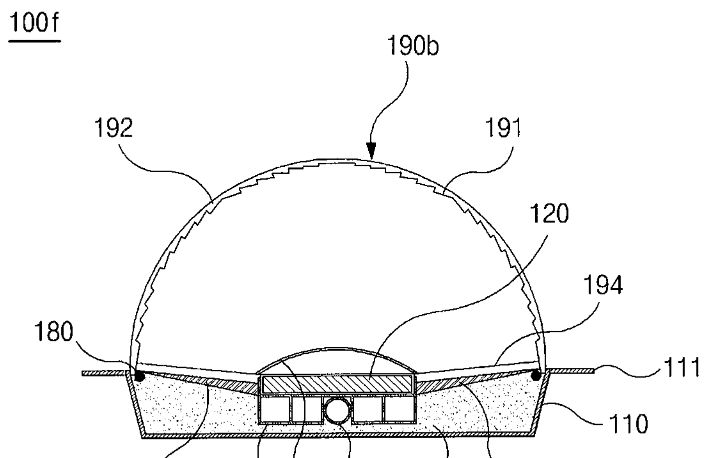

100f
190b
192
191
120
194
180
111
110
195
170
193
150
160
195

Fig. 17

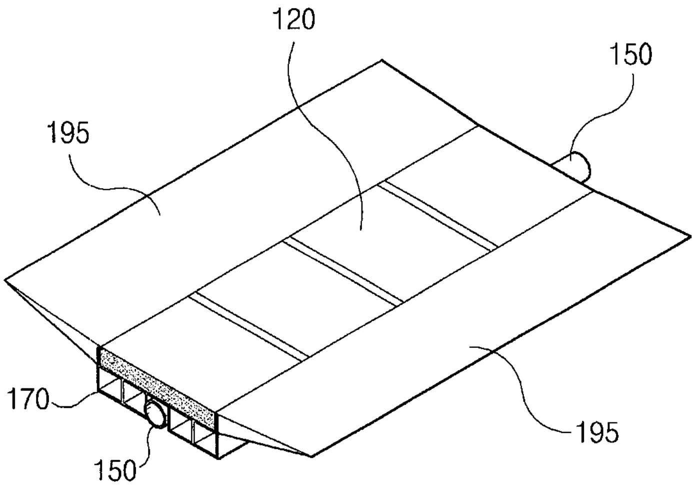


Fig. 18

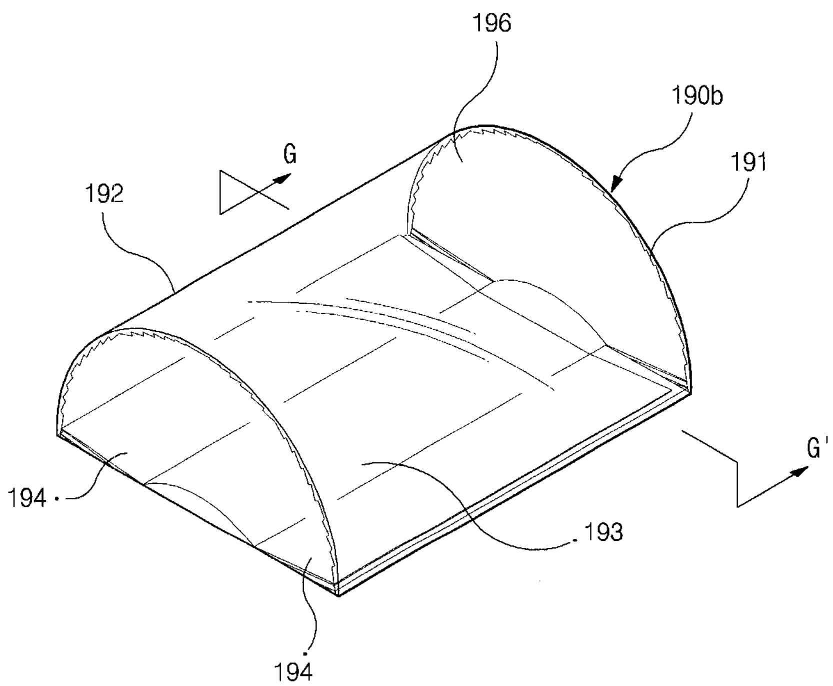


Fig. 19

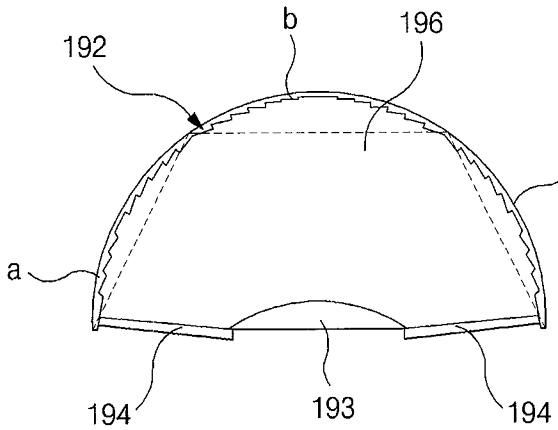

192
b
196
c
a
194
193
194

Fig. 20

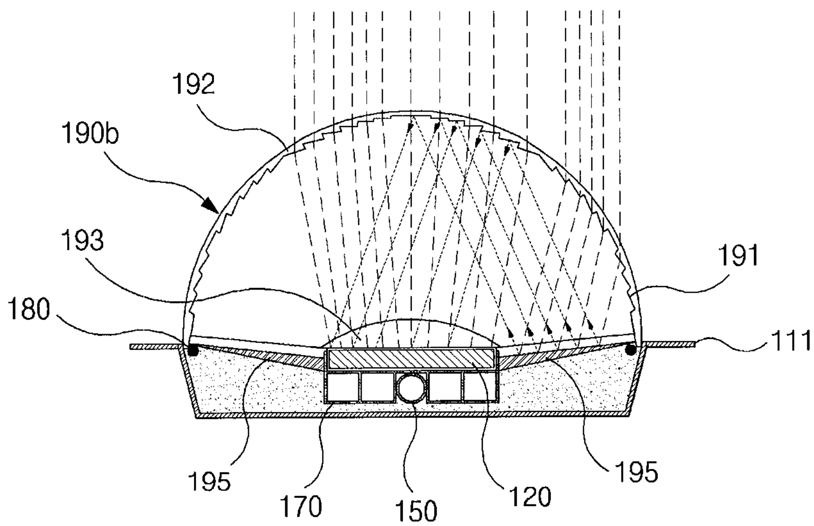

192
190b
193
191
180
111
195
170
150
120
195

Fig. 21

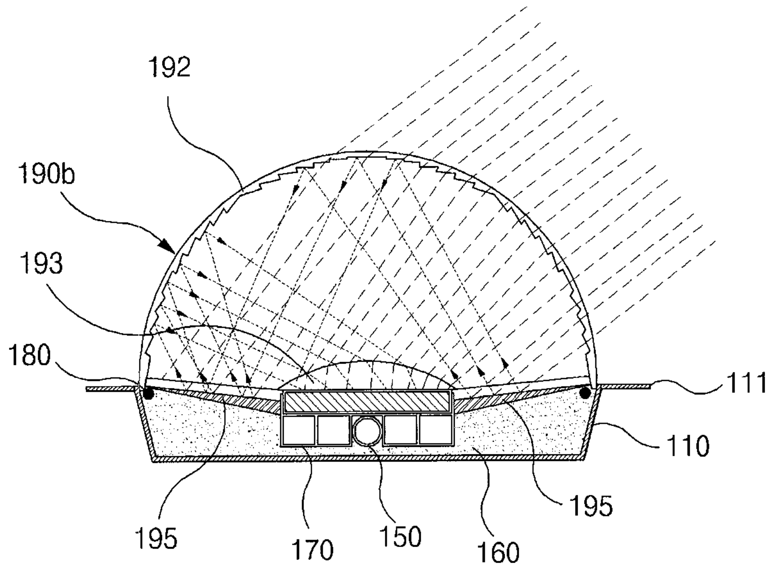

192
190b
193
180
111
110
195
195
170
150
160

Fig. 22

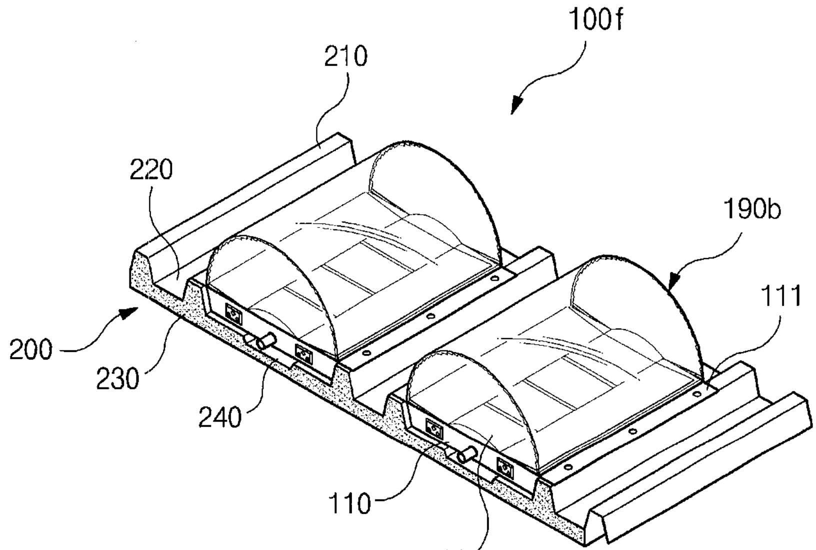

100f
210
220
190b
111
200
230
240
110
120

Fig. 23

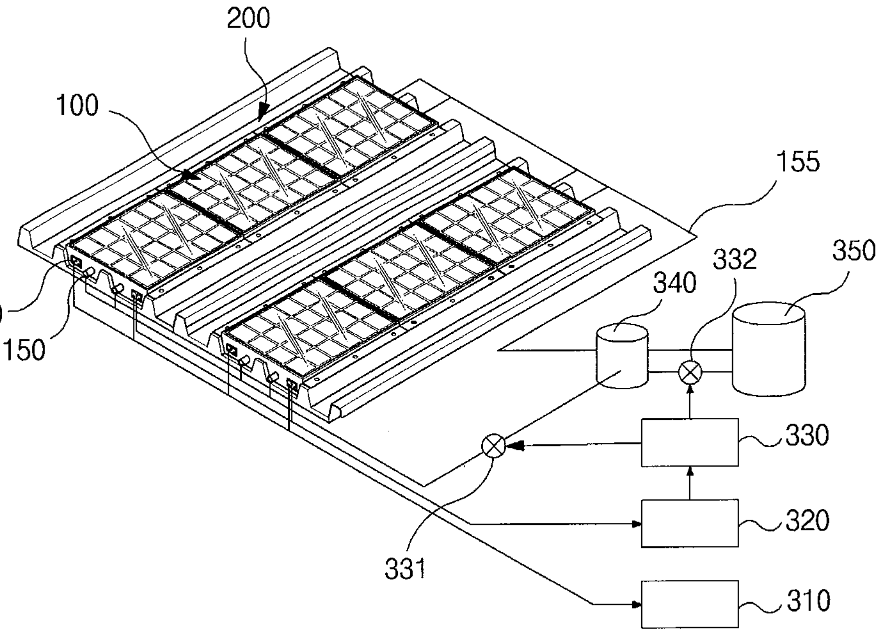

200
100
155
332
350
340
140
150
330
320
331
310

Fig. 24

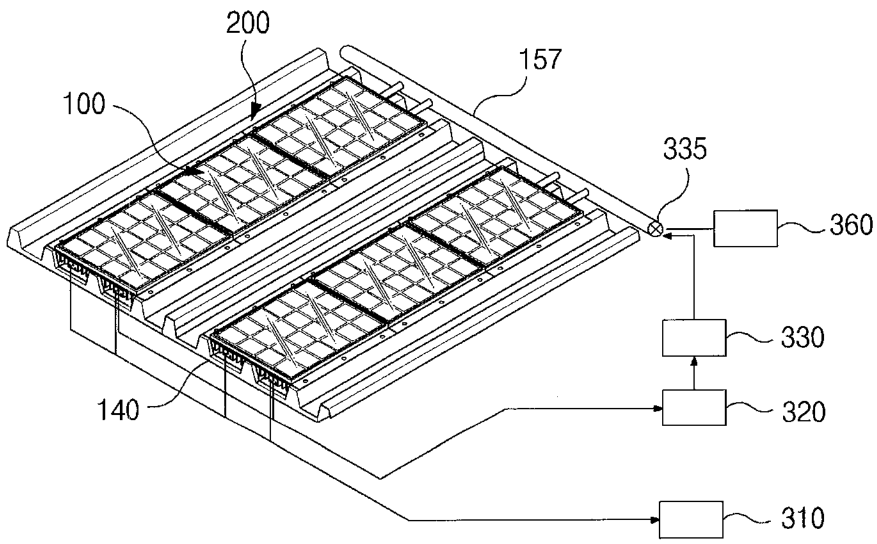

200
157
100
335
360
330
140
320
310

Fig. 25