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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
06 September 2019 (06.09.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/165503 A1

(51) International Patent Classification:
H01L 31/0232 (2014.01) *H01L 31/049* (2014.01)
H01L 31/0236 (2006.01) *H01L 31/052* (2014.01)
H01L 31/024 (2014.01) *H02S 40/20* (2014.01)
H01L 31/048 (2014.01) *H02S 40/42* (2014.01)

(21) International Application Number:
PCT/AU2019/050168

(22) International Filing Date:
27 February 2019 (27.02.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2018900640 27 February 2018 (27.02.2018) AU

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM,

(54) Title: A PHOTOVOLTAIC MODULE

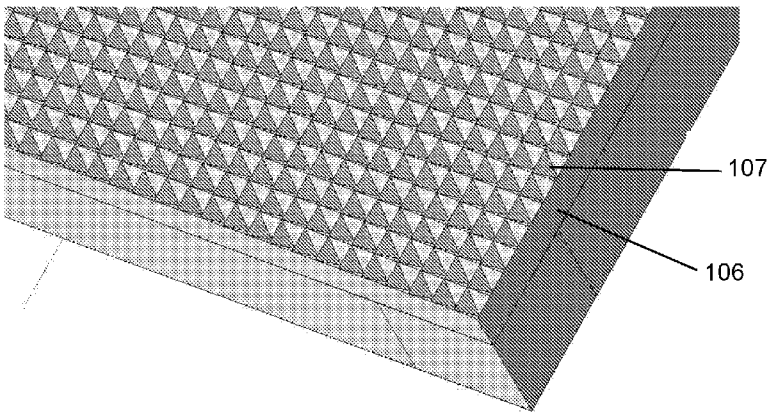

Figure 4

(57) **Abstract:** The present disclosure provides a photovoltaic module, which comprises a photon absorbing material comprising a solar cell; The photovoltaic module also comprises a glass material positioned within a plane and being positioned over the photon absorbing material such that in use light is incident on the glass material and the glass material transmits light towards the photon absorbing material, the glass material having a front surface facing away from the photon absorbing material. The front surface of the glass material has a shape which is profiled such that the emittance of infrared light from the front surface of the glass material is increased compared to that of a flat front surface, the emittance of the infrared light being associated with absorbance of infrared light that is incident upon the front surface. A rear backing sheet of the photovoltaic module may have a shape that is profiled in a corresponding manner.

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

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

Published:

— *with international search report (Art. 21(3))*

A PHOTOVOLTAIC MODULE

Technical Field of the Invention

The present invention relates to a photovoltaic module.

Background of the Invention

Photovoltaic modules are now used for various applications. It is known that the conversion efficiency of photovoltaic modules is adversely affected if the temperature of the photovoltaic modules increases. Photovoltaic modules often operate in bright sunlight, typically 20-30°C above ambient temperature. This not only reduces the energy production of a photovoltaic module by 0.4-0.5% (relative) for every degree increase in temperature (up to 15% for a 30°C increase in temperature), but also accelerates all known degradation processes and reduces the lifespan of the photovoltaic module below a lifespan that is otherwise achievable.

In addition, photovoltaic modules typically degrade 0.5% (relative) in output for each year in the field, with photovoltaic modules normally warranted to be above 80% of their initial rating after 25 years of field exposure. Further, long time testing of specific degradation modes suggest degradation rates approximately double for every 10°C increase in temperature. This suggests that photovoltaic modules operating at a temperature lower than the above-mentioned typical operating temperature could not only increase their energy production, but could also have a reduced degradation and could consequently be used for extended periods of time than otherwise possible.

Summary of the Invention

In accordance with a first aspect of the present invention there is provided a photovoltaic module comprising:

a photon absorbing material comprising a solar cell; and

a glass material being positioned within a plane and being position over the photon absorbing material such that in use light is incident on the glass material and the glass material transmits light towards the photon absorbing material, the glass material having a front surface facing away from the photon absorbing material;

wherein the front surface of the glass material has a shape which is profiled such that the emittance of infrared light from the front surface of the glass material is increased compared to that of a flat front surface, the emittance of the infrared light being associated with absorbance of infrared light that is incident upon the front surface within a predefined angular range relative to a surface normal of the plane in which the glass material is positioned.

The defined shape of the front surface of the glass material in use increases an amount of thermal energy radiated by the glass material particularly at oblique angles and consequently contributes to reducing the operating temperature of the photovoltaic module.

In one specific embodiment the front surface of the glass material has a shape which is profiled such that the

emittance of infrared radiation is increased compared to that of a flat front surface, the emittance of the infrared radiation being associated with absorption of light that is incident at oblique angles relative to a surface normal of the plane in which the glass material is positioned.

The front surface of the glass material may comprise structures, such as inverted pyramids or any other suitable type of recesses or projections. The recesses or projections may have surfaces that recess or project, respectively, from the plane in which the glass material is positioned an angle within the range of less than 90°-80°, 80°- 70°, 70°- 60°, 60° - 50°, 50° - 40°, 40° - 30°, 30° - 20°, 20° to 10° or less than 10°. Smaller angles are advantageous for cleaning purposes and preventing accumulation of particles, whereas larger angles have optical advantages.

The photovoltaic module may also comprise a rear backing sheet positioned such that the photon absorbing material is located between the glass material and the rear backing sheet, the rear backing sheet having a rear surface facing away from the photon absorbing material and having a shape which is profiled such that the emittance of infrared radiation is increased compared to that of a flat rear surface, the emittance being associated with absorption of infrared light that is incident upon the rear surface of the rear backing sheet within a predefined angular range relative to a surface normal of a plane in which the rear backing sheet is positioned.

The defined shape of the rear surface of the backing sheet in use increases an amount of thermal energy

radiated by the rear backing sheet particularly at oblique angles and consequently contributes to reducing the operating temperature of the photovoltaic module.

The rear backing sheet may be formed from a glass material.

The rear surface of the backing sheet may comprise structures, such as inverted pyramids or any other suitable type of recesses or projections. The recesses or projections may have surfaces that recess or project, respectively, from the plane in which the glass material is positioned an angle within the range of less than 90°-80°, 80°- 70°, 70°- 60°, 60° - 50°, 50° - 40°, 40° - 30°, 30° - 20°, 20° to 10° or less than 10°.

In accordance with a second aspect the present invention provides a photovoltaic module, comprising:

a glass material;

a photon absorbing material comprising a solar cell; and

a rear backing sheet positioned such that the photon absorbing material is located between the glass material and the rear backing sheet;

wherein the rear backing sheet has a rear surface facing away from the photon absorbing material, the rear surface having a shape which is profiled such that the emittance of infrared radiation is increased compared to that of a flat rear surface, the emittance being associated with absorption of infrared light that is incident upon the rear surface of the rear backing sheet within a predefined angular range relative to a surface

normal of a plane in which the rear backing sheet is positioned.

In one specific embodiment the rear surface of the rear backing has a shape which is profiled such that the emittance of infrared radiation is increased compared to that of a flat rear surface, the emittance of the infrared radiation being associated with absorption of light that is incident at oblique angles relative to a surface normal of the plane in which the rear backing sheet is positioned.

The rear surface of the backing sheet may also comprise structures, such as inverted pyramids or any other suitable type of recesses or projections. The recesses or projections may have surfaces that recess or project, respectively, from the plane in which the glass material is positioned an angle within the range of less than 90°- 80°, 80°- 70°, 70°- 60°, 60° - 50°, 50° - 40°, 40° - 30°, 30° - 20°, 20° to 10° or less than 10°.

The rear backing sheet may be formed from a glass material.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a photovoltaic module in accordance with an embodiment of the present invention;

Figure 2 is a graph showing the calculated emissivity

as a function of angle to the perpendicular;

Figure 3 is a schematic representation of a component of a photovoltaic module in accordance with an embodiment of the present invention; and

Figure 4 is a schematic representation of a component of a photovoltaic module in accordance with another embodiment of the present invention.

Detailed Description of Embodiments

A photovoltaic module in accordance with embodiments of the present invention is now described. Figure 1 schematically illustrates components of a photovoltaic module 100. The photovoltaic module 100 comprises a transparent encapsulant material 102 that encapsulates a solar cell 104, which in use absorb incident photons for electricity generation.

The photovoltaic module further comprises a glass material 106 that has a front surface 107. The photovoltaic module also comprises a back sheet 108 having a rear surface 109.

A person skilled in the art will appreciate that the photovoltaic module may comprise additional components which are omitted for clarity.

The front surface 107 of the glass material 106 has a shape which is profiled such that the emittance of infrared light from the front surface 107 of the glass material 106 is increased compared to that of a flat front surface. The emittance of the infrared light is associated with absorbance of infrared light that is incident upon the front surface 107 within a predefined angular range

relative to a surface normal of the plane in which the glass material 106 is positioned.

In one specific embodiment predefined angular range is an angular range of oblique angles.

The front surface may comprise structures, such as inverted pyramids or any other suitable type of recesses or projections. The recesses or projections may have surfaces that recess or project, respectively, from the plane in which the glass material is positioned at suitable oblique angles. As described above, smaller angles are advantageous for cleaning purposes and preventing accumulation of particles, whereas larger angles have optical advantages.

The rear surface 109 of the rear sheet 108 may have a shape that is profiled in the same manner as the front surface 107 of the glass material 106.

The profiled front surface 107 and the profiled rear surface 109 will be described in more detail further below.

Turning now to Figure 2, there are calculations of the glass emissivity for different angles relative to a surface normal of planar glass material. The calculation was performed for glass material, such as low-iron soda-lime glass, that absorbs incident electromagnetic radiation through stretched Si-O and Si-Si bonds and bent Si-O-Si bonds, at wavelengths in the proximity of 9 microns, 12 microns and 21 microns.

For example, the upper curve (showing the emission along the surface normal) of the graph shown in Figure 2 shows “dips” at wavelengths of approximately 9 microns and 21

microns, and a smaller dip at 12 microns, corresponding absorption associated with the above-mentioned bonds.

In particular the absorption at wavelengths of 12 microns and 21 microns by the glass material reduces the thermal emission from the glass and results in an increase in temperature of the photovoltaic module and consequently is unwanted (these strong absorption bands change the refractive index in the vicinity of these absorption bands, which in turn increases reflection and hence decreases absorption and emissivity in the vicinity of the absorption bands).

The calculated emissivity illustrated in Figure 2 shows the angular dependency of the emissivity. The emissivity decreases for increasing angles relative to the perpendicular.

The front surface 107 in accordance with embodiments of the present invention is profiled in a manner such that the emissivity especially at oblique angles is increased. The recesses or projections of the front surface 107 have surfaces that recess or project, respectively, as angles at which the emittance of infrared radiation (and associated absorption of incident infrared radiation) is increased compared to that of a flat front surface, which reduces heating of the photovoltaic module.

Figure 3 is a schematic illustration of a portion of the front surface of the glass material 106. The front surface 107 of the glass material 106 shown in Figure 3 has a profiled shape, which is arranged to avoid or reduce reflection of at least a portion of electromagnetic radiation incident upon the glass material and which would otherwise be reflected if the front surface were flat,

particularly for oblique angles of incidence. In this example, the front surface has an undulating surface profile and the undulations project at an angle of less than 30° from a direction determined by a general orientation of the front surface 107. Decreasing the glass reflection, particularly at oblique angles, increases the thermal energy emission of the glass.

Figure 4 shows a portion of a macro-structured front surface of a glass material 106 in accordance with a further embodiment of the present invention. In this example the front surface comprises a pattern of inverted pyramids.

A person skilled in the art will appreciate that the front surface may alternatively have a shape that is profiled in any other suitable manner that increases emissivity of infrared radiation at oblique angles.

In the above-illustrated examples the front surface 107 of the glass material 106 is macro-textured. Alternatively or additionally, the rear surface 109 of the back sheet 108 may be macro-textured and profiled in the same manner as the front surface 107 of the glass material 106 to increase loss of thermal radiation through the back sheet 108. The back sheet 108 may also be formed from glass.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments

are, therefore, to be considered in all respects as illustrative and not restrictive.

The Claims:

1. A photovoltaic module, comprising:

a photon absorbing material comprising a solar cell; and

a glass material being positioned within a plane and being position over the photon absorbing material such that in use light is incident on the glass material and the glass material transmits light towards the photon absorbing material, the glass material having a front surface facing away from the photon absorbing material;

wherein the front surface of the glass material has a shape which is profiled such that the emittance of infrared light from the front surface of the glass material is increased compared to that of a flat front surface, the emittance of the infrared light being associated with absorbance of infrared light that is incident upon the front surface within a predefined angular range relative to a surface normal of the plane in which the glass material is positioned.

2. The photovoltaic module of claim 1 wherein the front surface of the glass material has a shape which is profiled such that the emittance of infrared radiation is increased compared to that of a flat front surface, the emittance of the infrared radiation being associated with absorption of light that is incident at oblique angles relative to a surface normal of the plane in which the glass material is positioned.

3. The photovoltaic module of claim 1 or 2 comprising recesses or projections which have surfaces that recess or project, respectively, from the plane in which the glass material is positioned at an angle within the range of less than 90°- 80°, 80°- 70° or 70°- 60°.

4. The photovoltaic module of claim 1 or 2 comprising recesses or projections which have surfaces that recess or project, respectively, from the plane in which the glass material is positioned at an angle within the range of 60° - 50° 50° - 40°, or 40° - 30°.

5. The photovoltaic module of claim 1 or 2 comprising recesses or projections which have surfaces that recess or project, respectively, from the plane in which the glass material is positioned at an angle within the range of 30° - 20°, 20° to 10° or less than 10°.

6. The photovoltaic module of any one of the preceding claims further comprising a rear backing sheet positioned such that the photon absorbing material is located between the glass material and the rear backing sheet, the rear backing sheet having a rear surface facing away from the photon absorbing material and having a shape which is profiled such that the emittance of infrared radiation is increased compared to that of a flat rear surface, the emittance being associated with absorption of infrared light that is incident upon the rear surface of the rear backing sheet.

7. The photovoltaic module of claim 6 wherein the rear surface of the rear backing sheet has a shape which is profiled such that the emittance of infrared radiation is increased compared to that of a flat rear backing sheet, the emittance of the infrared radiation being associated with absorption of light that is incident at oblique angles relative to a surface normal of the plane in which the rear backing sheet is positioned.

8. The photovoltaic module of claim 6 or 7 wherein the rear backing sheet is formed from a glass material.

9. A photovoltaic module comprising:

a glass material;

a photon absorbing material for absorbing received electromagnetic radiation, the photon absorbing material comprising a solar cell; and

a rear backing sheet positioned such that the photon absorbing material is located between the glass material and the rear backing sheet;

wherein the rear backing sheet has a rear surface facing away from the photon absorbing material, the rear surface having a shape which is profiled such that the emittance of infrared radiation is increased compared to a that of a flat rear surface, the emittance of the infrared light being associated with absorbance of infrared light that is incident upon the rear surface of the rear backing sheet within a predefined angular range

relative to a surface normal of the plane in which the glass material is positioned.

10. The photovoltaic module of claim 8 wherein the rear surface of the rear backing sheet has a shape which is profiled such that the emittance of infrared radiation is increased compared to that of a flat rear backing sheet, the emittance of the infrared radiation being associated with absorption of light that is incident at oblique angles relative to a surface normal of the plane in which the rear backing sheet is positioned.

11. The photovoltaic module of claim 9 comprising recesses or projections which have surfaces that recess or project, respectively, from the plane in which the glass material is positioned at an angle within the range of less than 90°- 80°, 80°- 70°, 70°- 60° or 60° - 50°.

12. The photovoltaic module of claim 9 comprising recesses or projections which have surfaces that recess or project, respectively, from the plane in which the glass material is positioned at an angle within the range of 60° - 50°, 50° - 40°, 40° - 30°.

13. The photovoltaic module of claim 9 comprising recesses or projections which have surfaces that recess or project, respectively, from the plane in which the glass material is positioned at an angle within the range of 30° - 20°, 20° to 10° or less than 10°.

14. The photovoltaic module of any one of claims 9 to 13 wherein the rear backing sheet is formed from a glass material.

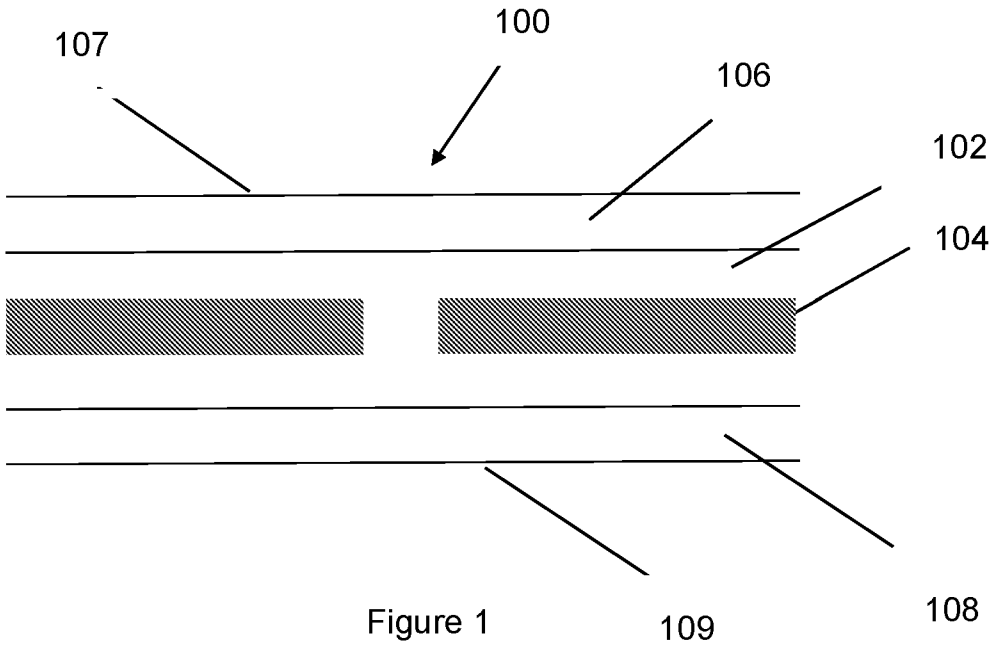

Figure 1

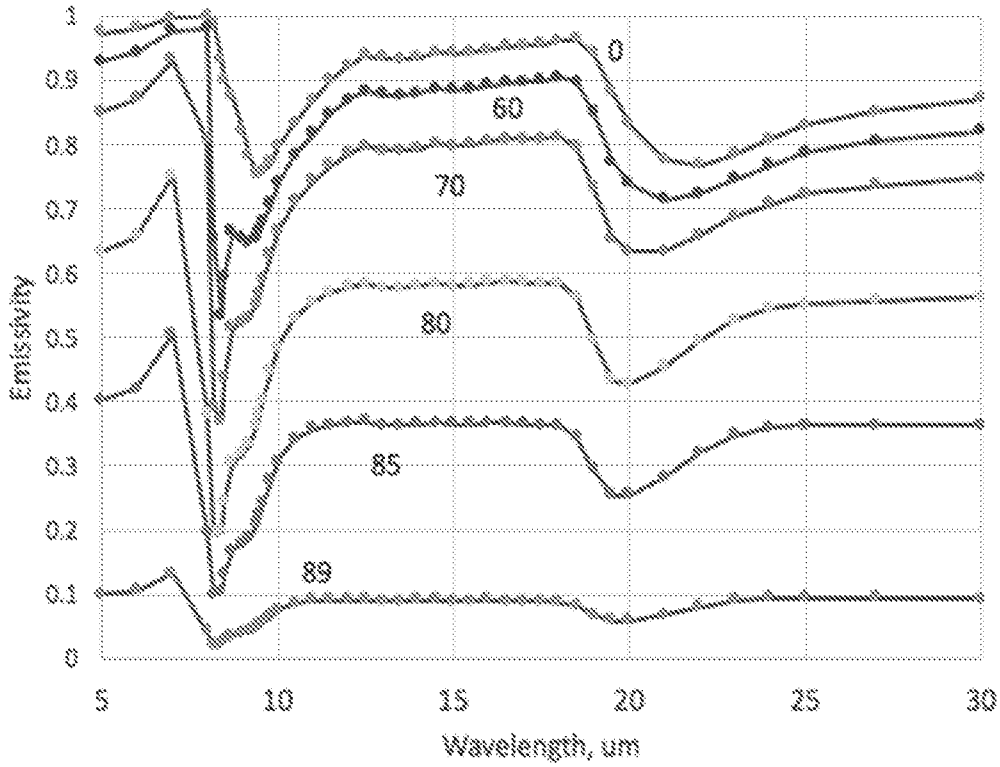

Figure C4: Calculated planar glass emissivity as a function of angle to the perpendicular.

Figure 2

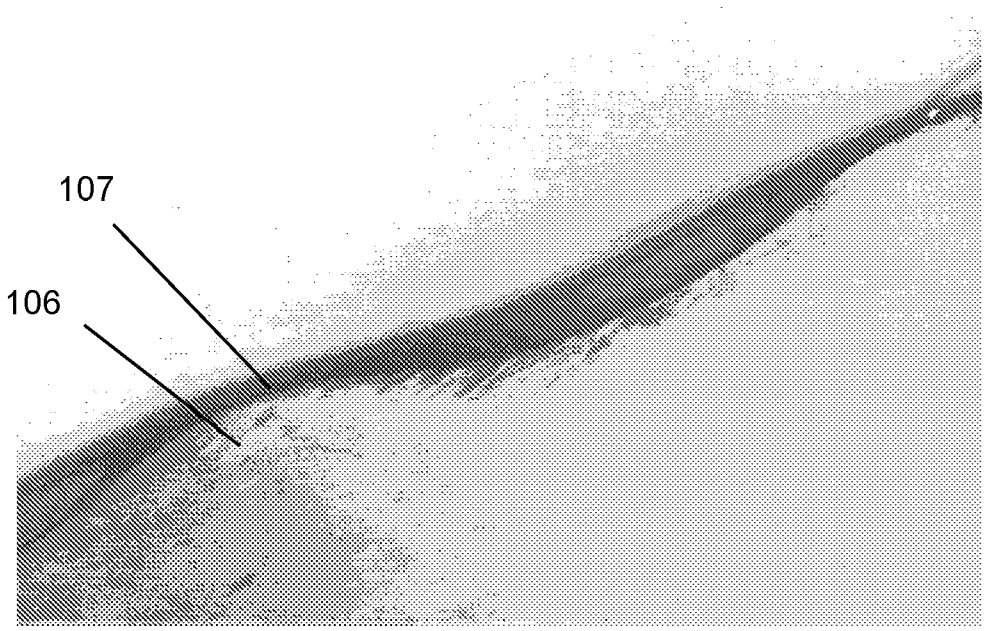

Figure 3

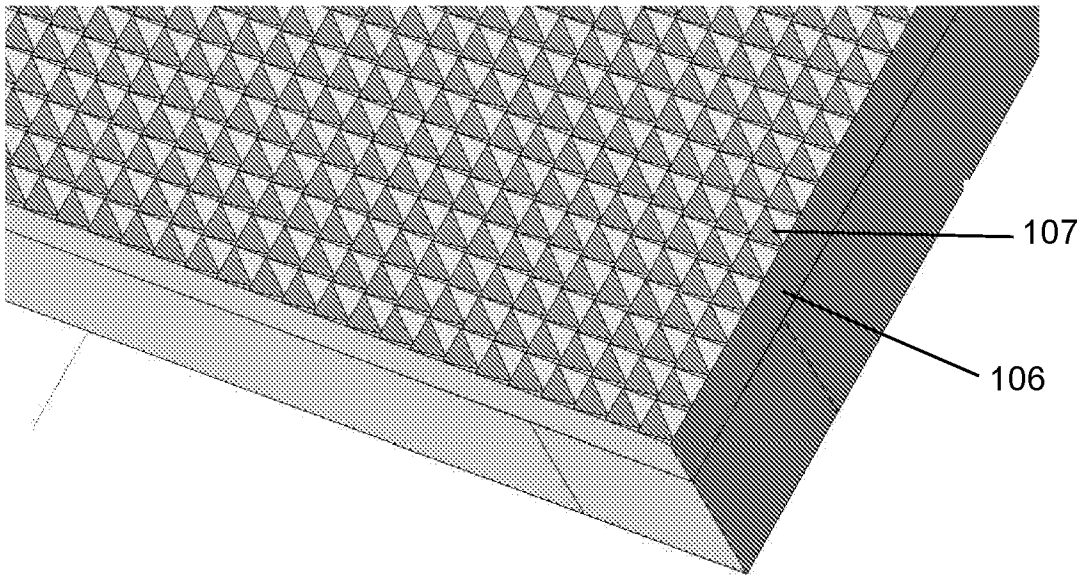

Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2019/050168

A. CLASSIFICATION OF SUBJECT MATTER

H01L 31/0232 (2014.01) ***H01L 31/0236 (2006.01)*** ***H01L 31/024 (2014.01)*** ***H01L 31/048 (2014.01)***
H01L 31/049 (2014.01) ***H01L 31/052 (2014.01)*** ***H01L 31/054 (2014.01)*** ***H02S 40/20 (2014.01)*** ***H02S 40/42 (2014.01)***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Database: PATENW (EPODOC, WPIAP and English full text databases). IPC and CPC: H01L 31/--; H01L 27/14 (and sub-marks); H02S 40/--; H01L 51/42 (and sub-marks); H01L 31/04 (and sub-marks); H01L 27/142 (and sub-marks); H01L 31/0236 (and sub-marks); H01L 31/052 (and sub-marks); H02S 40/42 (and sub-marks). CPC: Y02E 10/50 (and sub-marks); Y02P 70/521; H01L 31/0488; H01L 31/02366. Keywords: photovoltaic, PV, solar; glass; cover, front, rear, back, substrate, plate, sheet; profile, texture, uneven, pattern, protrusion, oblique, rough, shape; cool; reduce, lower, decrease, radiate, dissipate, spread; temperature, heat, thermal; pyramid, prism; angle, oblique; back, front, rear, surface; emission, radiate; infrared; AND LIKE TERMS. Database: Espacenet. Search terms: Newsouth Innovations Pty Limited (Applicant); Martin Andrew Green (Inventor), Yajie Jessica Jiang (Inventor), Mark Keevers (Inventor), Nicholas Ekins-Daukes (Inventor), Zibo Zhou (Inventor); H01L 31/0236 (IPC); H01L 31/048 (IPC); H01L 31/049 (IPC); H01L 31/02366 (CPC); H01L 31/0488 (CPC); H01L (IPC); H02S (IPC). Database: Auspat. Search terms: Newsouth Innovations Pty Limited (Applicant); Martin Andrew Green (Inventor), Yajie Jessica Jiang (Inventor), Mark Keevers (Inventor), Nicholas Ekins-Daukes (Inventor), Zibo Zhou (Inventor); H01L 31/0236 (IPC); H01L 31/048 (IPC); H01L 31/049 (IPC). Applicant and Inventor names searched in internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2019	13 May 2019
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Richard Baker AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262832583

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2019/050168**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 3214659 A1 (DSM IP ASSETS B.V.) 06 September 2017 Abstract, paragraphs 0014 to 0017 and 0020 to 0026, claims 1, 3, 4, figure 1	1-14
X	US 2010/0180929 A1 (RAYMOND et al.) 22 July 2010 Paragraphs 0012 to 0015, 0049, 0078, 0080 to 0082 and 0085, figures 4 to 6	1-5
X	US 2008/0115828 A1 (TAYLOR) 22 May 2008 Paragraphs 0017 to 0019 and 0025 to 0027, figures 1 to 3	1-5
X	US 2013/0344642 A1 (SAINT-GOBAIN GLASS FRANCE) 26 December 2013 Paragraphs 0018 and 0022 to 0025, figures 1 to 3.	1-5

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2019/050168**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
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		US 2008004833 A1	03 Jan 2008

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2019/050168**

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Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
		WO 2005111539 A1	24 Nov 2005
		WO 2005111670 A1	24 Nov 2005

End of Annex

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