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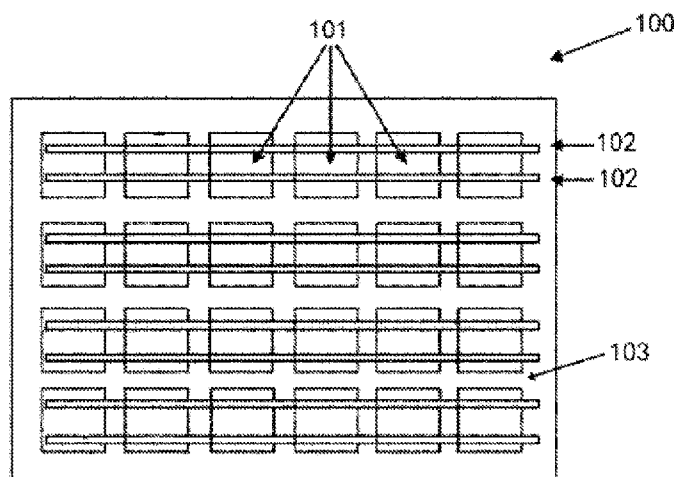


Fig.1

(57) Abstract: A photovoltaic module (100), has at least two solar cells (101) with cell gaps (103) therebetween; busbars and/or gridlines (102) on the at least two solar cells (101); and a front glass cover above the busbars and/or gridlines (102), wherein a local structure with a haze of at least 50% is provided on the upper surface of the front glass cover at positions corresponding to part or all of the projection areas of the busbars, the gridlines (102), the cell gaps (103) or a combination thereof. The photovoltaic module (100) has an improved transmittance of redirected light, and thereby can significantly increase the power output of the photovoltaic module (100). There is also a simple and easy method for preparing the photovoltaic module (100).



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PHOTOVOLTAIC MODULE COMPRISING GLASS COVER HAVING LOCAL STRUCTURE WITH IMPROVED HAZE AND PREPARATION METHOD THEREFOR

5 TECHNICAL FIELDS

The present invention generally relates to a photovoltaic module, more particularly, to a photovoltaic module comprising a glass cover having a local structure with improved haze and a preparation method therefor.

10

BACKGROUND OF INVENTION

In the long run, renewable energy will be the main source of energy for the future of mankind. Photovoltaic power generation is one of the rapidly developing renewable energy sources. Photovoltaic power
15 generation converts light energy to electrical energy via photovoltaic effect of solar cells. The voltage generated by a single solar cell is much lower than the voltage required for actual use. Accordingly, a plurality of solar cells are connected by wires, for example, busbars and gridlines, to form a photovoltaic module, also known as a solar panel, so as to provide higher
20 power output.

A typical photovoltaic module generally comprises a front cover, an encapsulant, a solar cell and a backsheet. Sunlight is incident through the front cover to the solar cell for energy conversion. Therefore, the factors affecting the power output of the photovoltaic module generally include
25 the net incident amount of sunlight arriving at the solar cell and the conversion efficiency of the solar cell per se. Not all incident sunlight can arrive at the solar cell and be converted to electrical energy. On the one hand, incident sunlight passes through several layers, such as the front cover and the encapsulant, to reach the solar cell. When light enters
30 another medium from one medium, reflection and refraction occur, which in turn causes a decrease in the amount of the light arriving at the solar cell. On the other hand, in the photovoltaic module, parts of the wires (for

example, busbars and gridlines) connecting the solar cells are located between the incident sunlight and the solar cells, such that some of the sunlight is shielded from reaching the solar cells. In addition, the solar cells are spaced apart in the photovoltaic module to form cell gaps between
5 each other. In those shadowed areas and cell gap areas, the photovoltaic module is unable to utilize incident sunlight, and thus inactive areas are formed. The presence of the inactive areas, as well as the reflection and refraction of the incident sunlight, causes the net incident amount of the sunlight reaching the solar cells to be less than the total amount of the
10 incident sunlight. Many methods have been proposed to improve the net incident amount of the sunlight reaching the solar cells so as to improve the power output of the photovoltaic module.

The pending patent application CN103048706A, which is incorporated herein by reference in its entirety, of the present applicant
15 discloses a method for applying an anti-reflection coating on the front cover to improve the transmittance of incident sunlight.

It has been proposed to use micro busbars and gridlines in a photovoltaic module, so as to reduce the shadowing effects imposed by the busbars and gridlines. However, the use of micro busbars and gridlines
20 may lead to a risk of reduced mechanical strength and short circuit.

It has also been proposed to redirect the sunlight incident on the inactive areas to the solar cells with reflection and refraction structures, so as to increase the net incident amount of the sunlight reaching the solar cell, and thereby improve the power output of the photovoltaic module. For
25 example, WO2013/148149, which is incorporated herein by reference in its entirety, discloses a light directing medium in the form of a strip of microstructured film carrying a light reflective layer, which directs light that would otherwise be incident on the inactive areas onto the solar cell. It has also been proposed to treat the glass cover by laser so as to reduce the
30 shadowing effect of the busbars and gridlines in the photovoltaic module.

Sandblasting is a common surface treating method which uses abrasives jetted at high speed to treat surface so as to achieve surface

cleaning, surface patterning and stress deformation. When sandblasting a glass surface, an irregular surface microstructure of the glass surface is imparted due to the hitting and cutting action of the abrasives on the glass surface. Such irregular surface microstructure may redirect the transmitted
5 light.

There is still a demand for a light management structure that is sufficient to significantly enhance the power output of a photovoltaic module.

Accordingly, the present invention is to provide a photovoltaic
10 module that satisfies the above demand by modifying its front glass cover to form a local structure with improved haze. The present invention also provides a method for preparing the front glass cover and the photovoltaic module. The present method forms a local structure with improved haze via sandblasting and has the characteristics of remarkable effect, simple
15 operation, easy control and environmental friendliness.

SUMMARY OF INVENTION

The present invention relates to such surprising finding that, a local structure with improved haze formed at a location corresponding to part or
20 all of the projection areas of the inactive areas (such as, busbars, gridlines, cell gaps or combination thereof) on the upper surface of the front glass cover of a photovoltaic module may cause the light incident on the inactive areas (diffusively) scattered, so that part of sunlight that would otherwise be incident on the inactive shadowed areas changes its direction when it
25 passes through the front glass cover, and thereby a part of it is incident onto adjacent solar cell. Accordingly, the adjacent solar cell can additionally utilize this part of incident light, thereby obtaining an improved power output.

In one embodiment of the present invention, provided is a
30 photovoltaic module comprising:

at least two solar cells with cell gaps therebetween;

busbars and/or gridlines on the at least two solar cells; and

a front glass cover above the busbars and/or gridlines,
wherein a local structure with improved haze is provided on the upper
surface of the front glass cover at positions corresponding to part or all of
the projection areas of the busbars, the gridlines, the cell gaps or a
5 combination thereof.

Another embodiment of the present invention is a method for
preparing a front glass cover for a photovoltaic module, comprising the
steps of:

sandblasting part areas of the upper surface of the front glass cover
10 with an abrasive selected from those having a microhardness (HV) of
greater than 600, to form a local structure with a haze of at least 50%;
applying an anti-reflection coating on the front glass cover; and
tempering the front glass cover coated with the anti-reflection coating.

A further embodiment of the present invention is a method for
15 preparing a photovoltaic module, comprising the steps of:

providing at least two solar cells with cell gaps therebetween;
arranging busbars and/or gridlines on the at least two solar cells;
arranging a front glass cover above the busbars and/or gridlines, and
sandblasting the upper surface of the front glass cover at positions
20 corresponding to part or all of the projection areas of the busbars, the
gridlines, the cell gaps or a combination thereof, with an abrasive selected
from those having a microhardness (HV) of greater than 600, to form a
local structure with a haze of at least 50%;
applying an anti-reflection coating on the front glass cover; and
25 tempering the front glass cover coated with the anti-reflection coating.

BRIEF DESCRIPTION OF DRAWINGS

The drawings are used to assist in a further comprehension of the
present invention and constitute part of the specification, and, together
30 with the following detailed description, to illustrate the present invention
but not intended to limit the present invention. In the drawings:

Fig. 1 is a top view of solar cells for a typical photovoltaic module;

Fig. 2 is a graph showing the relationship between haze and transmittance;

Fig. 3A is an electron micrograph of a laser-etched glass surface; and

Fig. 3B is an electron micrograph of a sandblasted glass surface.

5

DETAILED DESCRIPTION

The term "a front glass cover" as used herein refers to the front glass cover per se, or to the front glass cover having the local structure and/or coated with the anti-reflection coating after processing.

10 The term "projection area" as used herein refers to the areas on the front glass cover corresponding to the busbars, the gridlines, the cell gaps in the top view.

The term "part or all of the projection areas" as used herein refers to, for example, 10-100%, 20-100%, 30-100%, 40-100%, 50-100%, 60-100%,
15 70-100%, 80-100%, 90-100% or 100% of the projection areas.

The term "haze" as used herein characterizes the light scattering degree of a transparent or translucent material. It is defined as the percentage of the flux of the transmitted light deviating from the incident direction greater than 2.5 degrees over the total flux of the transmitted light,
20 when a beam of parallel light of a standard light source is vertically illuminated onto the transparent or translucent material.

The term "improved haze" as used herein refers to a haze of greater than about 50%, preferably greater than about 70%, more preferably greater than about 80%, even more preferably greater than about 90%, and
25 most preferably greater than about 95%.

The term "transmittance" as used herein refers to the percentage of the flux of transmitted light over the flux of incident light.

The terms "above" and "on" as used herein refer to both "directly above" and "indirectly above" and both "directly on" and "indirectly on".
30 That is, other object is optionally present therebetween.

One aspect of the present invention relates to a photovoltaic module, comprising:

at least two solar cells with cell gaps therebetween;
busbars and/or gridlines on the at least two solar cells; and
a front glass cover above the busbars and/or gridlines,

wherein a local structure with improved haze is provided on the upper
5 surface of the front glass cover at positions corresponding to part or all of
the projection areas of the busbars, the gridlines, the cell gaps or a
combination thereof.

As shown in Fig. 1, a typical photovoltaic module 100 comprises a
plurality of solar cells 101. Any type of solar cell can be used in the
10 photovoltaic module, for example, a thin film solar cell, a monocrystalline
silicon solar cell, a polycrystalline silicon solar cell, an organic solar
device, and the like. To collect the charge carriers generated in the silicon
material, a highly conductive metal such as aluminum or silver is deposited
on the front and back sides of the solar cells to form gridlines 102. To be
15 most effective in current collection, dense parallel gridlines are typically
deposited by metallization in front of individual solar cells. The gridlines
connect busbars (not shown) which collect current from the gridlines. To
provide sufficient conductivity, the busbars are much wider than the
gridlines. The gridlines and busbars are opaque and thereby block the
20 incident sunlight from reaching the solar cells. In addition, the plurality of
solar cells are spaced apart in the photovoltaic module. Accordingly, there
are cell gaps 103 between each other. It is clear that the sunlight incident
on the cell gaps cannot be utilized by the solar cells. In this regard, the
areas shadowed by the gridlines and busbars and the cell gap areas form
25 inactive areas of the photovoltaic module. That is, the incident light
thereon cannot be utilized by the solar cells.

The photovoltaic module further comprises a front glass cover which
is positioned above the solar cells and their gridlines and/or busbars.
Exemplary materials suitable for the front glass cover include
30 soda-lime-silica based glass. In some embodiments of the present invention,
a local structure with improved haze is provided on the upper surface of
the front glass cover at the positions corresponding to part or all of the

projection areas of the inactive areas. The local structure is located at positions corresponding to part or all of the projection areas of the busbars, the gridlines, the cell gaps or a combination thereof. In some embodiments, the local structure has a haze of greater than about 50%, preferably greater than about 70%, more preferably greater than about 80%, even more preferably greater than about 90%, and most preferably greater than about 95%. In some embodiments, the local structure has a surface roughness (Ra) of about 0.1-10 μm , preferably about 0.5-5 μm . In some embodiments, the local structure has a transmittance of redirected light of greater than about 2%, preferably greater than about 3.5%, and more preferably greater than about 4%.

The photovoltaic module further comprises a backsheet. In some embodiments, the backsheet includes an electrically insulating material. Suitable materials may include, for example, glass, quartz, a polymer, or a polymer reinforced with a fiber (e.g. a glass, ceramic or polymeric fiber). In some embodiments, the backsheet includes glass or quartz. Exemplary glass materials include soda-lime-silica based glass. In other embodiments, the backsheet includes a polymer, preferably a multilayer polymer.

In some embodiments, encapsulant is interposed between the front glass cover and the backsheet, surrounding the solar cells and the gridlines and the busbars. The encapsulant may be made of a suitable light-transparent, electrically non-conducting material. Some exemplary encapsulants include thermosettable fluoropolymers, acrylic resins, ethylene vinyl acetate (EVA), polyvinyl butyral, polyolefins, thermoplastic polyurethanes, clear polyvinylchloride, and ionomers.

In use, the encapsulant is placed in the form of discrete sheets on and/or below the solar cells between the front glass cover and the backsheet, then heated under vacuum to cause the encapsulant to liquefy so as to flow around and encapsulate the solar cells, while simultaneously filling any voids between the front glass cover and the backsheet, and cooled to solidify the liquefied encapsulant. In some embodiments, the encapsulant may be cured in situ to form a transparent solid matrix.

Additionally, the encapsulant may be adhered to the front glass cover and/or the backsheet.

According to one aspect of the present invention, provided is a method for preparing a front glass cover for a photovoltaic module,
5 comprising the steps of:

sandblasting part areas of the upper surface of the front glass cover with an abrasive selected from those having a microhardness (HV) of greater than 600, to form a local structure with a haze of at least 50%;

applying an anti-reflection coating on the front glass cover; and

10 tempering the front glass cover coated with the anti-reflection coating.

According to one aspect of the present invention, provided is a method for preparing a photovoltaic module, comprising the steps of:

providing at least two solar cells with cell gaps therebetween;

arranging busbars and/or gridlines on the at least two solar cells;

15 arranging a front glass cover above the busbars and/or gridlines, and sandblasting the upper surface of the front glass cover at positions corresponding to part or all of the projection areas of the busbars, the gridlines, the cell gaps or a combination thereof, with an abrasive selected from those having a microhardness (HV) of greater than 600, to form a
20 local structure with a haze of at least 50%;

applying an anti-reflection coating on the front glass cover; and

tempering the front glass cover coated with the anti-reflection coating.

In some embodiments, the sandblasting process may be a dry blasting process or a wet blasting process, preferably a dry blasting process using
25 compressed air. Typical sandblasting processing conditions may be used. For example, the sandblasting pressure may be about 0.1-0.5 MPa; the sandblasting angle may be about 30-60°, or about 80-90°; the sandblasting height may be about 1-30 cm, preferably 5-15 cm; and the sandblasting coverage may be greater than about 100%, preferably greater than about
30 150%, and most preferably greater than about 200%.

The abrasive has a hardness greater than that of the front glass cover. For example, the suitable abrasives may have a microhardness (HV) of

greater than about 600, preferably greater than about 800, most preferably greater than about 1000. Suitable abrasive may be selected from the group consisting of quartz sand, corundum sand, silicon carbide sand, zirconium corundum sand, zirconia sand, zirconium silicate sand and combinations thereof. Said corundum sand includes, for example, white corundum, brown corundum, monocrystalline corundum or the like. There are no specific requirements on the shape of the abrasives. Preferred abrasives may be sharp sand and spherical sand. Said sharp sand may be those with irregular shape or those with regular shape. If a sharp abrasive is used, it preferably has a particle size of F500 - F60 ($d_{50} = 0.01-0.3$ mm), more preferably an average particle size of about 0.01-0.2 mm, and most preferably an average particle size of about 0.01-0.1 mm. If a spherical abrasive is used, it preferably has an average particle size of about 0.125 mm or less, more preferably about 0.075 mm or less. In addition, if a sharp abrasive is used, it is preferably to use a sandblasting angle of about 60° , and if a spherical abrasive is used, it is preferably to use a sandblasting angle of about $80-90^\circ$.

In some embodiments, after forming the local structure with improved haze on the upper surface of the front glass cover, the local structure may be subjected to a secondary sandblasting, wherein the secondary sandblasting uses an abrasive having an average particle size smaller than that used in the sandblasting for forming the local structure with improved haze, so as to further improve the haze.

After forming the local structure with improved haze on the upper surface of the front glass cover, an anti-reflection coating may be applied on the front glass cover. The anti-reflection coating comprises a porous layer, and optionally a sublayer between the porous layer and the front glass cover. The sublayer is non-porous. The sublayer has a solid content of about 2-5 wt%, and a thickness of about 20-110 nm. The porous layer has a solid content of about 2-10 wt%, a porosity of about 40-70 % by volume, and a thickness of about 100-500 nm, preferably about 100-400 nm, and more preferably about 100-250 nm.

In some embodiments, the sublayer is deposited by providing a silica gel-containing solution, coating the solution on the front glass cover, and drying. In some embodiments, the porous layer is deposited by providing a silica gel-containing solution, incorporating silica pellets having a particle size of about 50-300 nm, preferably about 80-250 nm, and more preferably about 100-200 nm and polymeric beads into the solution to form a suspension, and depositing the resulting suspension on the front glass cover or on the sublayer, if present.

In one variant, the sublayer is formed as follows. Tetraethyl orthosilicate (TEOS) is mixed with a hydrochloric acid aqueous solution having a pH of 2 at a weight ratio of about 1:0.1-10, preferably about 1:0.5-5, more preferably about 1:1-2, for example, about 1:1.5, to form a silica gel-containing solution. The resulting solution is deposited on the front glass cover. The deposition may be carried out by blade coating, curtain coating, spin coating or the like, preferably by spin coating wherein the spin speed is about 500-2000 rpm. Finally, the sublayer is formed by drying at 100°C for 5-10 minutes.

In one variant, the porous layer is deposited as follows. TEOS is mixed with a hydrochloric acid aqueous solution having a pH of 2 at a weight ratio of about 1:0.1-10, preferably about 1:0.5-5, more preferably about 1:1-2, for example, about 1:1.5, to form a silica gel-containing solution. To the solution, incorporated are about 1-5 wt% of polymeric beads which are polymethyl methacrylate (PMMA) having a particle size of about 20-100 nm. Further to the solution, incorporated are about 0.1-5 wt% of silica pellets having a particle size of about 50-300nm, preferably about 80-250nm, and more preferably about 100-200nm. The resulting suspension is deposited on the front glass cover or on the sublayer, if present. The deposition may be carried out by blade coating, curtain coating, spin coating or the like, preferably by spin coating wherein the spin speed is 500-2000 rpm.

The front glass cover coated with the anti-reflection coating is tempered. In one embodiment, the tempering comprises heating the front

glass cover coated with the anti-reflection coating to a temperature near the softening point of the front cover glass for a period of time, and then quickly cooling. In one embodiment, the front glass cover coated with the anti-reflection coating is heated to 600-750 °C for 120-180 seconds, and
5 then quenched to room temperature, to finish the tempering.

It is believed that the tempering of the front glass cover coated with the anti-reflection coating affects both the anti-reflection coating and the front glass cover. On the one hand, during the heating stage of tempering, the polymeric beads in the porous layer are burned off, leaving voids to
10 form pores of the porous layer. The presence of the porous structure may provide additional light scattering. On the other hand, the high temperature treatment as well as the application of the anti-reflection coating can affect the microstructure of the local structure formed on the upper surface of the front glass cover, thereby reducing its haze. The upper surface of the front
15 glass cover obtained in the present method has a local structure with improved haze and is coated with the anti-reflection coating, wherein the local structure coated with the anti-reflection coating still has a haze of greater than about 50%, preferably greater than about 70%, more preferably greater than about 80%, even more preferably greater than about
20 90%, and most preferably greater than about 95%; and a transmittance of redirected light of greater than about 2%, preferably greater than about 3.5%, and more preferably greater than about 4%. At the same time, the tempering can eliminate the internal stress of the front glass cover, thereby enhancing its strength.

25 Surprisingly, it has been found that the local structure with improved haze provided on the upper surface of the front glass cover enables the photovoltaic module according to the present invention to have a higher transmittance of redirected light than conventionally designed photovoltaic modules. Such improved optical efficiency will substantially increase the
30 power output of the photovoltaic module.

As described below, the haze and transmittance of redirected light of various samples were measured, wherein the comparative sample was a

front glass cover only coated with an anti-reflection coating, and the test samples were those having different hazes by sandblasting the upper surfaces and coated with the anti-reflection coating. The results were shown in Fig. 2. In Fig. 2, the transmittance of redirected light of the comparative sample was not zero, which is attributable to the fact that the anti-reflection coating contains a porous layer. The porous structure can provide a weak light scattering effect. According to the results of Fig. 2, as the haze is increased, i.e. from a haze of 6.5% of the comparative sample to a haze of 31.8-93.6% of the test samples, the transmittance of redirected light is increased accordingly. Correspondingly, the increment of the transmittance of redirected light attributed by the increase in haze is also improved. This means that the solar cell receives some of the sunlight that would otherwise be incident on the inactive areas (i.e. the redirected light). The amount of the redirected light is increased as the haze of the local structure is increased. Accordingly, this portion of additional incident sunlight is converted by the solar cell into a power output increment.

Without being bound to any theory, it is believed that the local structure with improved haze of the present invention are derived from the irregular surface microstructure formed by sandblasting the front glass cover. The irregular surface microstructure imparts the local structure with improved haze and increased roughness. However, some treatments result in increased roughness but no significantly increase in haze. Figs. 3A and 3B respectively show an electron micrograph of a laser-etched glass surface and an electron micrograph of a sandblasted glass surface. The surfaces obtained by the two treatments may have similar surface roughness (Ra) but totally different haze. Laser etching is performed by irradiating a laser beam onto the surface of the material to be treated which absorbs the energy of the laser beam and is melted. Due to the directionality of laser beam, a groove profile is formed on the treated surface. Such groove profile enhances the roughness of the surface. However, the groove profile has little scattering effect on light, but more refractive effect. Accordingly, the laser-etched glass surface does not have

a significantly enhanced haze.

Property measurements

Haze was measured as follows: The side of the sample having an anti-reflection coating and/or the local structure was used as the side facing the incident light, and haze was measured at the opposite side with BYK-Gardner haze-gard plus AT-4725.

Surface roughness (Ra) was measured as follows: Surface roughness (Ra) was measured with Hommel Tester 1000, a contact roughness meter, by the steps of cleaning the surface of the sample, placing the measuring probe on the surface to be measured, and reading and recording the Ra value given by the contact roughness meter.

Transmittance of redirected light was measured as follows: The side of the sample coated with anti-reflection coating was covered with a black tape, leaving a slot of 2 mm * 24 mm in the center of the black tape. This side was used as the side facing the incident light. On the opposite side, only the area corresponding to the slot was covered with the black tape. The side of the sample facing the incident light was vertically irradiated with sunlight ($\lambda=300-1200$ nm), and transmittance was measured with a spectrophotometer, Lambda 950 from the opposite side. The cover treatment of the sample simulates the situation that light is incident on the inactive area. The transmitted light is the light that would otherwise be incident on the inactive area but is redirected by the sample (i.e. redirected light). Some of the redirected light will be incident onto the solar cell. Accordingly, the measured transmittance is named as transmittance of redirected light.

EXAMPLES

The features and advantages of the present invention will be apparent from the following examples. The examples are intended to be illustrative and not to limit the present invention in any way.

LIST OF REAGENTS:

White corundum sand: commercial available from Saint-Gobain Ceramic Materials (zhengzhou) Co., Ltd., WA F100, a sharp sand

5 Zirconia beads: commercial available from Saint-Gobain zirpro Ceramic Materials Co., Ltd., Zirpro Microblast B205, a spherical sand

Single crystal corundum sand: commercial available from Saint-Gobain Ceramic Materials (zhengzhou) Co., Ltd., MA88 F80, a sharp sand

10 White corundum sand for secondary sandblasting: commercial available from Washington Mills, WA F400, a sharp sand

TEOS: tetraethyl orthosilicate, a commercial available reagent

Hydrochloric acid: a commercial available reagent, concentration: 36 wt%

15 PMMA beads: commercial available polymethyl methacrylate beads with a particle size of 50nm

Silica pellets: commercial available, with a particle size of 100nm

LIST OF APPARATUS

20 Air suction sandblasting machine: 开信TM air suction sandblasting machine

Spectrophotometer: Lambda 950

Spin coating machine: commercial available

PREPARATION EXAMPLE 1

25 SANDBLASTING

The upper surface of a front glass cover was covered with a protective film. The protective film on positions corresponding to part or all of the projection areas of the busbars, the gridlines and the cell gaps was removed. The exposed areas of the upper surface of the front glass cover which were
30 outside the protective film were treated in an air suction sandblasting machine, wherein the sandblasting was performed by using an irregular sharp white corundum sand with a particle size of F100 (d50 =150-125

μm), at a sandblasting pressure of 0.3 MPa, a sandblasting angle of 60°, a sandblasting distance of 10 cm and a sandblasting coverage of 200%.

The parameters of the sandblasted areas were measured as described above: the surface roughness (Ra) was 3.5 μm, the haze was 97% and the
5 transmittance of redirected light was 5.09%.

APPLYING AN ANTI-REFLECTION COATING

TEOS and an aqueous hydrochloric acid solution having a pH of 2 were mixed in a weight ratio of 1:1.5 to prepare 500 g of a silica gel-containing solution, which was further added with the aqueous
10 hydrochloric acid solution having a pH of 2 to 2000 g. The resulting solution was deposited by a spin coating machine at 1000 rpm on the sandblasted front glass cover from which the protective film had been removed. The coating was dried at 100 °C for 10 minutes, to form a sublayer with a thickness of 50 nm.

15 TEOS and an aqueous hydrochloric acid solution having a pH of 2 were mixed in a weight ratio of 1:1.5 to prepare 500 g of a silica gel-containing solution, which was further added with the aqueous hydrochloric acid solution having a pH of 2 to 1850 g. To the solution, 100 g of PMMA beads with a particle size of 50 nm was added, and then 50 g
20 of silica pellets with a particle size of 100 nm was added. The resulting solution was deposited by a spin coating machine at 1000 rpm on the sublayer, to form a coating with a thickness of 150 nm.

TEMPERING

The front glass cover coated with the anti-reflection coating was
25 heated to 700 °C for 120 seconds, and then quenched to room temperature.

A front glass cover having a local structure formed by sandblasting on the upper surface and coated with an anti-reflection coating was obtained.

The parameters of the sandblasted areas were measured again: the surface roughness (Ra) was 3.5 μm, the haze was 94.4% and the
30 transmittance of redirected light was 5.04%.

PREPARATION EXAMPLE 2

SANDBLASTING

The upper surface of a front glass cover was covered with a protective film. The protective film on positions corresponding to part or all of the projection areas of the busbars, the gridlines and the cell gaps was removed.

5 The exposed areas of the upper surface of the front glass cover which were outside the protective film were treated in an air suction sandblasting machine, wherein the sandblasting was performed by using spherical zirconia beads Zirpro Microblast B205 (having a particle size of 0-63 μm) at a sandblasting pressure of 0.3 MPa, a sandblasting angle of 85° , a
10 sandblasting distance of 10 cm and a sandblasting coverage of 200%.

The parameters of the sandblasted areas were measured as described above: the surface roughness (Ra) was 2.3 μm , the haze was 93.8% and the transmittance of redirected light was 4.89%.

The steps of applying an anti-reflection coating and tempering in the
15 preparation example 1 were repeated. A front glass cover having a local structure formed by sandblasting on the upper surface and coated with an anti-reflection coating was obtained. The parameters of the sandblasted areas were measured again: the surface roughness (Ra) was 2.3 μm , the haze was 91.4% and the transmittance of redirected light was 4.33%.

20

PREPARATION EXAMPLE 3

The upper surface of a front glass cover was covered with a protective film. The protective film on positions corresponding to part or all of the projection areas of the busbars, the gridlines and the gaps was removed.

25 The exposed areas of the upper surface of the front glass cover which were outside the protective film were treated in an air suction sandblasting machine, wherein the sandblasting was performed by using an irregular sharp single crystal corundum sand with a particle size of F80 ($d_{50}=180\text{-}212\text{ }\mu\text{m}$) at a sandblasting pressure of 0.3 MPa, a sandblasting
30 angle of 60° , a sandblasting distance of 10 cm, and a sandblasting coverage of 200%. Then, a secondary sandblasting was carried out in the same air suction sandblasting machine, wherein the secondary sandblasting was

performed by using a white corundum sand with a particle size of F400 ($d_{50}= 20-40\ \mu\text{m}$) at a sandblasting pressure of 0.3 MPa, a sandblasting angle of 60° , a sandblasting distance of 10 cm, and a sandblasting coverage of 200%.

5 The parameters of the sandblasted areas were measured as described above: the surface roughness (R_a) was $4\ \mu\text{m}$, the haze was 97.3% and the transmittance of redirected light was 6.07%.

10 The steps of applying an anti-reflection coating and tempering in the preparation example 1 were repeated. A front glass cover having a local structure formed by sandblasting on the upper surface and coated with an anti-reflection coating was obtained. The parameters of the sandblasted areas were measured again: the surface roughness (R_a) was $4\ \mu\text{m}$, the haze was 96.3% and the transmittance of redirected light was 5.54%.

15 Those skilled in the art will understand that changes may be made to the above embodiments without departing from the inventive concept. Accordingly, it should be understood that the present invention is not limited by the specific embodiments disclosed, and includes various modifications within the spirit and scope of the present invention as defined by the appended claims.

20

LIST OF REFERENCE SIGNS

- 100 a photovoltaic module
- 101 a solar cell
- 102 gridlines
- 25 103 cell gaps

CLAIMS

1. A photovoltaic module, comprising:
at least two solar cells with cell gaps therebetween;
5 busbars and/or gridlines on the at least two solar cells; and
a front glass cover above the busbars and/or gridlines,
characterized in that a local structure with a haze of at least 50% is
provided on the upper surface of the front glass cover at positions
corresponding to part or all of the projection areas of the busbars, the
10 gridlines, the cell gaps or a combination thereof.
2. The photovoltaic module of claim 1, further comprising an
anti-reflection coating on the front glass cover.
- 15 3. The photovoltaic module of claim 1, further comprising:
a backsheet under the at least two solar cells; and
an encapsulant between the front glass cover and the backsheet.
4. The photovoltaic module of claim 1 or 2, wherein the local
20 structure has a surface roughness (Ra) of 0.5-5 μm .
5. The photovoltaic module of claim 1 or 2, wherein the local
structure has a transmittance of greater than 4%.
- 25 6. The photovoltaic module of claim 2, wherein the anti-reflection
coating comprises a porous layer and optionally, a sublayer between the
porous layer and the front glass cover.
7. The photovoltaic module of claim 6, wherein the sublayer has a
30 solid content of 2-5 wt%, and a thickness of 20-110 nm.
8. The photovoltaic module of claim 6, wherein the porous layer has a

solid content of 2-10 wt%, a porosity of 40-70 % by volume, and a thickness of 100-500 nm.

9. A method for preparing a front glass cover for a photovoltaic module, comprising the steps of:

sandblasting part areas of the upper surface of the front glass cover with an abrasive selected from those having a microhardness (HV) of greater than 600, to form a local structure with a haze of at least 50%;

applying an anti-reflection coating on the front glass cover; and

tempering the front glass cover coated with the anti-reflection coating.

10. A method for preparing a photovoltaic module, comprising the steps of:

providing at least two solar cells with cell gaps therebetween;

arranging busbars and/or gridlines on the at least two solar cells;

arranging a front glass cover above the busbars and/or gridlines, and sandblasting the upper surface of the front glass cover at positions corresponding to part or all of the projection areas of the busbars, the gridlines, the cell gaps or a combination thereof, with an abrasive selected from those having a microhardness (HV) of greater than 600, to form a local structure with a haze of at least 50%;

applying an anti-reflection coating on the front glass cover; and

tempering the front glass cover coated with the anti-reflection coating.

11. The method of claim 9 or 10, wherein the abrasive is selected from the group consisting of quartz sand, corundum sand, silicon carbide sand, zirconium corundum sand, zirconia sand, zirconium silicate sand and a combination thereof.

12. The method of claim 9 or 10, wherein the abrasive is in a form of sharp sand or spherical sand.

13. The method of claim 9 or 10, wherein the abrasive is a sharp abrasive having a particle size of F500-F60 with $d_{50} = 0.01-0.3$ mm.

14. The method of claim 9 or 10, wherein the abrasive is a spherical
5 abrasive having an average particle size of 0.125 mm or less.

15. The method of claim 9 or 10, wherein the processing conditions of the sandblasting are a sandblasting pressure of 0.1-0.5 MPa; a sandblasting angle of $30-60^\circ$, or $80-90^\circ$; a sand blasting height of 1-30 cm; and a
10 sandblasting coverage of greater than 100%.

16. The method of claim 9 or 10, further comprising, after the sandblasting, a secondary sandblasting, wherein the secondary sandblasting uses an abrasive having an average particle size smaller than
15 that used in the sandblasting.

17. The method of claim 9 or 10, wherein the applying of the anti-reflection coating on the front glass cover includes the steps of: optionally applying a sublayer, and applying a porous layer.
20

18. The method of claim 16, wherein the applying of the sublayer includes the steps of: providing a silica gel-containing solution, and coating the solution on the front glass cover.

25 19. The method of claim 16, wherein the applying of the porous layer includes the steps of: providing a silica gel-containing solution, incorporating silica pellets having a particle size of 50-300 nm and polymeric beads into the solution, and depositing the resulting suspension on the front glass cover or on the sublayer, if present.

30

20. The method of claim 16, wherein the applying of the sublayer includes the steps of:

mixing tetraethyl orthosilicate with an aqueous hydrochloric acid solution in a weight ratio of 1:1.5, to form a silica gel-containing solution, wherein the aqueous hydrochloric acid solution has a pH of 2;

depositing the resulting solution by spin coating, wherein the spin
5 speed is about 500-2000 rpm; and
drying at 100 °C for 5-10 minutes.

21. The method of claim 18, wherein the applying of the porous includes the steps of:

10 mixing tetraethyl orthosilicate with an aqueous hydrochloric acid solution at a weight ratio of 1:1.5, to form a silica gel-containing solution, wherein the aqueous hydrochloric acid solution has a pH of 2;

incorporating into the solution, 1-5 wt% of polymeric beads that are polymethyl methacrylate having a particle size of 20-100 nm;

15 further incorporating into the solution, 0.1-5 wt% of silica pellets having a particle size of 50-300 nm; and

depositing the resulting suspension by spin coating, wherein the spin speed is 500-2000 rpm.

20 22. The method of claim 9 or 10, wherein the tempering includes the steps of:

heating the front glass cover coated with the anti-reflection coating to 600-750 °C for 120-180 seconds, and

quenching to room temperature.

25

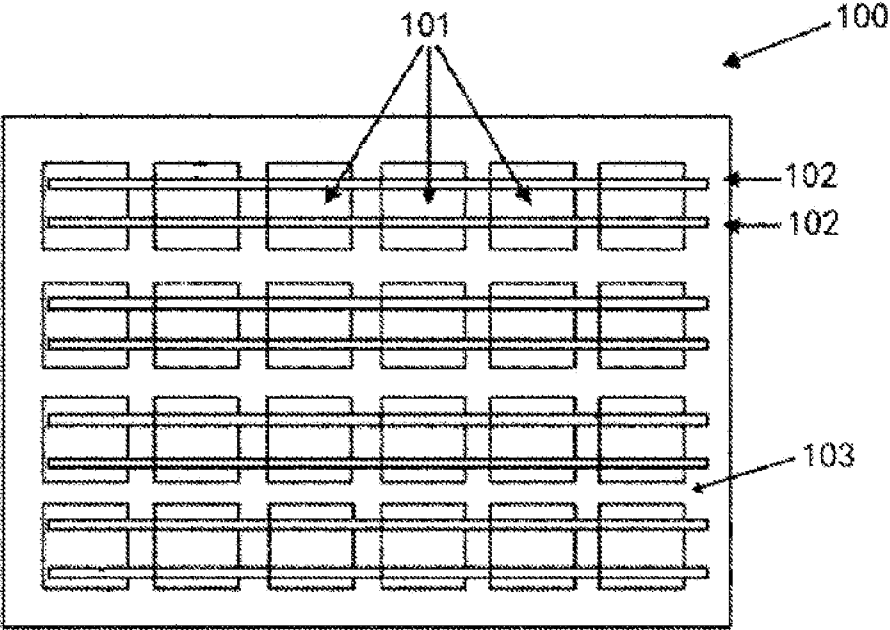
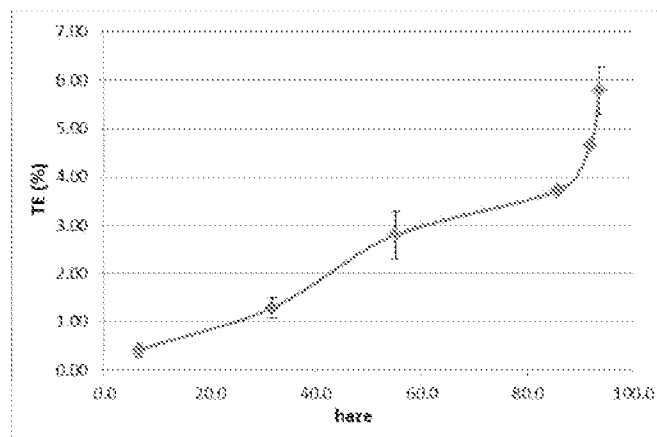


Fig.1

	Haze(%)	TE(%)	Δ TE(%)
The comparative sample	6.5	0.41	0.00
The sandblasted test samples	31.8	1.29	0.89
	55.0	2.80	2.39
	85.7	3.73	3.33
	91.8	4.64	4.23
	93.6	5.78	5.38

**Fig.2**

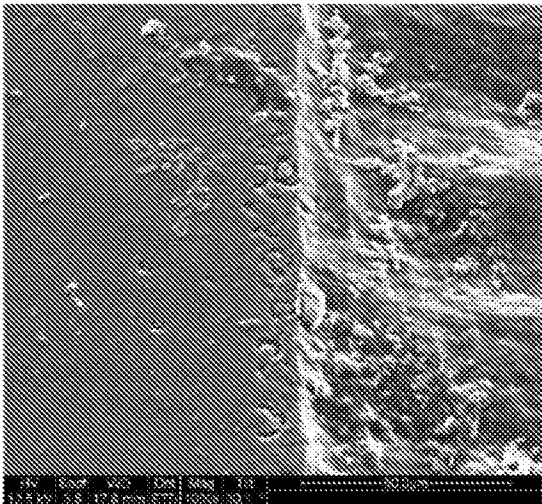


Fig. 3A

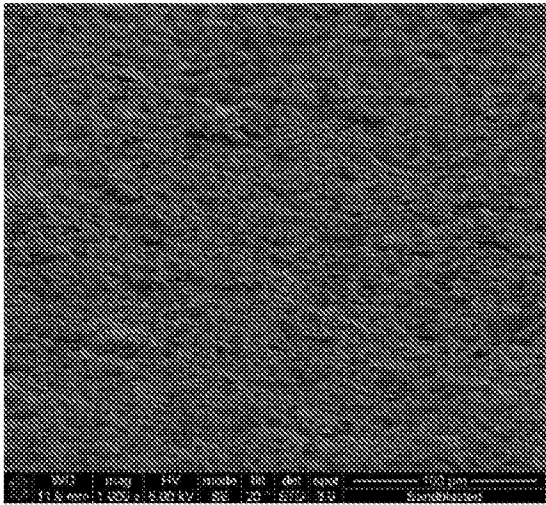


Fig. 3B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2019/071156

A. CLASSIFICATION OF SUBJECT MATTER

H01L 31/0216(2014.01)i

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)

H01L

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)

CNPAT,CNKI,WPLEPODOC: photovoltaic, solar, haze, roughness, texture, sand, abrasive, grip, grit, blast, blow, spray, jet, eject, shot, front, cover, glass, substrate, part, portion, section, anti, reflect

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2017034457 A1 (SOLIBRO RESEARCH AB) 02 March 2017 (2017-03-02) description, page 3, line 1 to page 5, line 2, and figures 1-2b	9, 11-22
Y	CN 102126831 A (JIANGSU GUOJI ENERGY SCI.&TECHNOLOGY CO., LTD.) 20 July 2011 (2011-07-20) description, paragraphs [0010]-[0048], and figure 1	9, 11-22
A	CN 102044581 A (CEEG SOLAR SCI. & TECHNOLOGY CO., LTD.) 04 May 2011 (2011-05-04) description, paragraphs [0023]-[0024], and figures 1-2	1-22
A	US 2014332073 A1 (SOUTHERN TAIWAN UNIVERSITY OF SCIENCE AND TECHNOLOGY) 13 November 2014 (2014-11-13) the whole document	1-22
A	CN 105609576 A (ZHANGJIAGANG XIEXIN INTEGRATION TECHNOLOGY) 25 May 2016 (2016-05-25) the whole document	1-22
A	CN 105977331 A (UNIV. CHANGCHUN SCI. & TECHNOLOGY) 28 September 2016 (2016-09-28) the whole document	1-22

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

22 March 2019

Date of mailing of the international search report

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Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2019/071156

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CN	105977331	A	28 September 2016	None			