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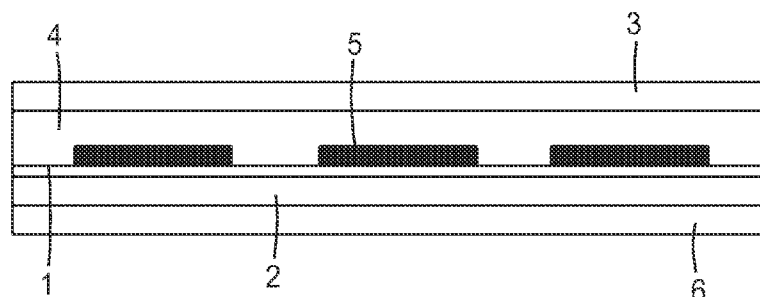


FIG. 2

(57) **Abstract:** The present invention provides an encapsulation material for a solar cell and a solar cell module using the encapsulation material. The encapsulation material comprises an encapsulation material layer (2) and a non-woven fabric layer (1), wherein the non-woven fabric layer (1) has a gram weight of 5 to 100 g/m² and a permeability of from 710 to 11,000 L/m²/s. The encapsulation material of the present application can effectively avoid overflow issues relating to a conventional encapsulation material, thereby avoiding numerous undesired results. Additionally, the solar cell module of the present invention is advantageous in a number of aspects, such as, for example, greater safety, better operability and lower costs, etc. Upon aging, the encapsulation material of the present invention exhibits much better adhesive strength than that in the prior art.



ENCAPSULATION MATERIAL FOR SOLAR CELL AND MODULE**Technical Field of the Invention**

5 The present application relates to an encapsulation material for solar cells. More specifically, the present invention relates to an overflow-free encapsulation material and a solar cell module using the encapsulation material.

Technical Background of the Invention

10 Solar energy is an inexhaustible and highly efficient clean energy source. A solar cell uses solar energy directly and efficiently, however, the wide use of solar energy will depend on whether it can be competitive with conventional electrical power in the aspect of cost per watt generated. One way of reducing the cost for generating one watt of electricity is to improve the power generating efficiency of a solar cell through technical innovation, while another way is to
15 reduce its costs, including material costs, manufacturing costs, etc. With the long development of solar cells, solar cell manufacturing technology has become mature, and thus it would be very difficult to achieve a breakthrough in power generating efficiency in a short period of time without additional costs or affecting mass production capabilities. Therefore, reducing costs and improving efficiency are of equal importance.

20 When a solar cell is encapsulated, a front side encapsulation material and a back side encapsulation material are generally required. Since the back side encapsulation material does not contact the light-facing surfaces of the cell components, it will not block the sunlight and there are no particular requirements with respect to the transmittance of the back side encapsulation material. In recent years, a number of manufacturers use a highly reflective
25 material, for example, a white EVA, to serve as the back side encapsulation material, which can reflect the sun light such that the cell can again receive the reflected sunlight to further improve the output efficiency. Various tests have shown that, regardless of the type of cell, whether monocrystalline or polycrystalline, the highly reflective back side white encapsulation material can reflect the sunlight to be reabsorbed by the cell, thereby significantly improving the output
30 power of the cell. This is particularly true for a solar cell module which is encapsulated by double glass. However, during the lamination process the white encapsulation material is prone to overflow, which may cover part of the solder strips or even cover the cells, which would result

in disadvantageous effects on the appearance, output power and efficiency of the solar cell module.

Summary of the Invention

One objective of the present invention is to solve the above problems in the prior art and provide a low cost encapsulation material which is capable of avoiding overflow while not affecting the performance of a solar cell module.

Currently, various methods for avoiding overflow have been provided. One method is using a double-layer encapsulation material, which means a transparent encapsulation material is added between the cell and the back side white encapsulation material. Since the transparent encapsulation material itself will absorb sunlight, the performance improvement resulting from the reflectivity of the white encapsulation material will be affected. Additionally, the double-layer encapsulation material has to be put in place with a special co-extrusion device, as a simple transformation of a conventional extrusion device will not work. In addition, the transparent encapsulation material is relatively expensive. Another method for solving the problem is to employ an encapsulation material having a low fluidity to decrease flow of the encapsulation material in the laminating process thereby avoiding overflow. However, an encapsulation material of low fluidity is typically accompanied by issues in the conventional manufacturing process, such as extremely high pressure of the melt, low production speed and so forth, which seriously affect production efficiency. In order to decrease the pressure of the melt and increase the speed, the temperature must be raised. However, in extrusion at a relatively high temperature, a gel may be easily generated and other disadvantageous situations may arise, and the extrusion device itself may even be damaged. Thus this process is very hard to control and is nearly impossible to perform in actual production.

According to an aspect of the present invention, an encapsulation material for a solar cell is provided. The encapsulation material for a solar cell comprises an encapsulation material layer and a non-woven fabric layer, wherein the non-woven fabric layer has a gram weight of 5 to 100 g/m² and a permeability of 710 to 11,000 L/m²/s. In certain implementations, the gram weight of the non-woven fabric layer is selected from the values of the following: 10 to 70 g/m², 5 g/m², 15 g/m², 20 g/m², 30 g/m², and 100 g/m². In certain implementations, the permeability of the non-woven fabric layer is selected from the values of the following: 1,000-6,500 L/m²/s,

710 L/m²/s, 2,914 L/m²/s and 11,000 L/m²/s. For example, in one embodiment, the non-woven fabric layer has a gram weight of 5 g/m² and a permeability of 11,000 L/m²/s. In another embodiment, the non-woven fabric layer has a gram weight of 100 g/m² and a permeability of 710 L/m²/s. In another embodiment, the non-woven fabric layer has a gram weight of 30 g/m² and a permeability of 2,914 L/m²/s. By employing a non-woven fabric layer with an appropriate gram weight and permeability, the overflow caused by the encapsulation material layer can be avoided effectively. The gram weight and permeability of the non-woven fabric material are important factors to implement the present disclosure. On one hand, the bigger the gram weight and thicker of the non-woven fabric material, the better the anti-overflow effect will be, but the related costs will be higher. On the other hand, the permeability of the non-woven fabric layer being too small may affect dispersion of the encapsulation material layer in the non-woven fabric layer, and may directly affect the adhesive force of the encapsulation material.

In particular, the non-woven fabric layer may be disposed on the encapsulation material layer, or may partially or completely enter the encapsulation material layer, depending on the pressure applied and the permeability of the non-woven fabric material. As such, the extent of the bonding between the non-woven fabric material and the encapsulation material layer can be controlled as needed. Meanwhile, the encapsulation material has an appropriate adhesive force and the solar cell module has an acceptable appearance and performance.

In some embodiments, the non-woven fabric layer is formed of a fiber material or a slice material.

In some embodiments, the fiber material includes a natural fiber, a regenerated fiber, a synthetic fiber or an inorganic fiber.

In some embodiments, the natural fiber may include a cotton fiber, a linen fiber, wool or silk. The regenerated fiber may include a bamboo fiber, a soybean fiber, a tencel fiber, a modal fiber or a polylactic acid fiber. The synthetic fiber may include a polypropylene fiber, a polyester fiber, a polyacrylonitrile fiber, a bicomponent fiber, a nylon fiber, a polyethylene fiber, a rayon fiber, a polyurethane fiber, or a mixture of two or more than two polymer fibers as mentioned above. The inorganic fiber may include a ceramic fiber, a boron fiber, a metal fiber or a carbon fiber.

In some embodiments, the slice material may include polyethylene, polypropylene, polyester or nylon.

In the present invention, the short fiber of the non-woven fabric layer has a length of 10 to 100 mm and a fiber fineness of 0.5 to 100 D (Daniels). In certain embodiments, the length of the short fiber of the non-woven fabric layer is selected from the values: 10 to 90 mm and 38 to 76 mm. In certain embodiments, the fiber fineness of the short fiber of the non-woven fabric layer is selected from the values: 0.5 to 50 D, 1 to 20 D and 1.5 to 15 D. Any value of the length of the short fiber as described above can be combined with any value of the fineness of the short fiber as described above. The smaller the fiber fineness, the higher the density of the fiber will be, which means the lower the permeability.

In some embodiments, the cross section of the short fiber of the non-woven fabric layer has a circular or irregular shape.

According to one embodiment, the encapsulation material is formed of an ethylene-vinyl acetate (EVA) copolymer. It should be noted that, with the wide use of polyolefin (PO) copolymer that is prepared by polyethylene (PE) and EVA, the present invention also applies to the encapsulation material layer formed of PO. In addition, a person skilled in the art will understand that the encapsulation material layer may also comprise a mixture of several different polymers, so long as the material of the encapsulation material layer has an appropriate complex viscosity. In certain embodiments, the encapsulation material layer has a complex viscosity of from 80 Pa*s to 154,000 Pa*s under conditions where the shear frequency is 0.0158 Hz and the temperature is 120°C. Or, in certain embodiments, the encapsulation material layer has a complex viscosity of 54 Pa*s to 1,117 Pa*s under conditions where the shear frequency is 39.8 Hz and the temperature is 120°C.

In the present invention, the encapsulation material layer is often referred to as a reflective encapsulation material layer. In this case, "reflective encapsulation material" includes not only a high reflectivity encapsulation material, but also a low transmittance encapsulation material which may be at risk of overflowing to the top of a solar cell and blocking the sunlight. In certain implementations, the transmittance of the encapsulation material is less than 80%, and the encapsulation material layer of the present disclosure may be white, semitransparent, or colored.

According to another aspect of the present invention, a solar cell module is provided. The solar cell module comprises a plurality of cells and a back side glass attached to the cells by the encapsulation material as described above, wherein the encapsulation material is used as a

back side encapsulation material and the non-woven fabric layer is disposed facing the cells. In this way, the solar cell module may be configured to be in a stack structure comprising a front side glass, a front side encapsulation material, cells, and a back side encapsulation material/back side glass. Alternatively, the solar cell module may also be configured to comprise a single side glass only. In other words, according to the present invention, the solar cell module is only provided with a front side glass attached to the cells, while the back side glass is replaced by a back panel.

Compared with the prior art, the present invention can effectively avoid overflow of the encapsulation material in the encapsulation material layer onto the top of the cells by employing encapsulation material formed of the non-woven fabric material and the encapsulation material layer. The overflow of the encapsulation material results in some undesired consequences, such as, for example, blocking the sunlight, decreasing the power generating efficiency of the cells, and affecting the appearance of the cell module. Additionally, compared with the prior art, the solar cell module of the present invention is advantageous in a number of aspects, such as, for example, greater reliability, greater safety, better operability and lower production costs. The inventors have found that, upon aging, the encapsulation material of the present invention exhibited much better adhesive force than those in the prior art. Additionally, upon aging, the power attenuation level of the solar cell module of the present invention was similar to the power attenuation level of the solar cell module of the prior art.

Brief Description of the Drawings

The other advantages and novel characteristics of the present invention will be understood more clearly by the detailed description below with reference to the accompanying drawings, wherein:

FIG. 1 illustrates schematically an encapsulation material according to one of the preferred embodiments of the present invention; and

FIG. 2 illustrates schematically a solar cell module according to one of the preferred embodiments of the present invention.

FIG. 3 illustrates interlayer delamination of white EVA.

FIG. 4 illustrates the penetration of white EVA through nonwoven fabric and its adhesion to glass.

5 Detailed Description of the Invention

As shown in FIG. 1, in one embodiment, the encapsulation material for a solar cell according to the present invention is comprised of an encapsulation material layer 2 and a non-woven fabric layer 1 attached to the encapsulation material layer 2.

10 Process of attaching the non-woven fabric layer to the encapsulation material layer

Any suitable process known in the art, such as hot pressing, extrusion, etc., can be employed to attach the non-woven fabric layer 1 to the encapsulation material layer 2. For example, the non-woven fabric layer may be placed directly on the encapsulation material layer, or the encapsulation material may be melted at a certain temperature and extruded onto the non-woven fabric layer to have the encapsulation material layer flow and extend onto the non-woven fabric layer. After this, the encapsulation material layer and the non-woven fabric layer may be subjected to a lamination process to have them attached securely to each other. In certain embodiments, additional adhesive may be coated between the non-woven fabric layer and the encapsulation material layer to increase the adhesive strength therebetween. Additionally, in certain embodiments, if it is desired to achieve an optimal adhesive effect between the non-woven fabric layer and the cells, an additional encapsulation material layer may be coated or extruded onto the surface of the non-woven fabric layer facing the cell.

Upon the lamination process being completed, in certain embodiments, the non-woven fabric layer 1 may be disposed on the encapsulation material layer 2, or partially enter or completely enter the encapsulation material layer 2 thereby avoiding overflow of the encapsulation material and ensuring that the encapsulation material has an appropriate adhesive force upon aging.

Non-woven fabric layer material

For achieving the results as described above, in certain embodiments, it is advantageous that the gram weight of the non-woven fabric layer 1 is in a range of 5 to 100 g/m². And, in

certain embodiments, the permeability of the non-woven fabric layer 1 is in a range of 710 to 11,000 L/m²/s. The above values are obtained under test conditions where the differential pressure is 200 Pa and the area under test is 20 cm², by following the test criteria EDANA1401.

In some embodiments, the non-woven fabric layer 1 is an end product or a semi-finished product obtained by following a dry laying process, a spun laying process or a wet laying process. For example, the dry laying process may include carding laying, air laying and thermal bonding or hot rolling.

Additionally, in certain embodiments, the non-woven fabric layer 1 may be formed of a fiber material. The fiber material includes a natural fiber, a regenerated fiber, a synthetic fiber or an inorganic fiber. Examples of the natural fiber include a cotton fiber, a linen fiber, wool or silk. Examples of the regenerated fiber may include a bamboo fiber, a soybean fiber, a tencel fiber, a modal fiber or polylactic acid fiber, and the like. Examples of the synthetic fiber include a polypropylene fiber, a polyester fiber, a polyacrylonitrile fiber, a bicomponent fiber, a nylon fiber, a polyethylene fiber, a rayon fiber, a polyurethane fiber, or a mixture of two or more than two polymer fibers as mentioned above, and the like. Examples of the inorganic fiber include a ceramic fiber, a boron fiber, a metal fiber or a carbon fiber, and the like. Alternatively, the non-woven fabric layer 1 may also be formed of a slice material. The slice material includes, such as, for example, polyethylene, polypropylene, polyester, nylon, or the like.

In one implementation, the short fiber of the non-woven fabric layer 1 has a length of 10 to 100 mm and a fiber fineness of 0.5 to 100 D, and the cross section of the short fiber is configured to be in a circular or an irregular shape.

Material of the encapsulation material layer

If the material of the encapsulation material layer has a low fluidity, the encapsulation material thus obtained may have a better anti-overflow performance. However, in the present invention, the reflective encapsulation material layer does not necessarily have a low fluidity. In fact, given a suitable non-woven fabric layer 1 having an appropriate gram weight as well as appropriate permeability, a number of encapsulation materials may be employed to achieve a relatively satisfactory result, such as an encapsulation material having a complex viscosity of from 80 Pa*s to 154,000 Pa*s under conditions where the shear frequency is 0.0158 Hz and the temperature is 120°C, and an encapsulation material layer having a complex viscosity of from 54

Pa*s to 1,117 Pa*s under conditions where the shear frequency is 39.8 Hz and the temperature is 120°C. The complex viscosity of an encapsulation material layer may be measured by a torque rheometer (model no. ARES-G2) which is available from TA Instruments, United States. The possibility of overflow will be lower with the increase of the complex viscosity.

5

Solar cell module

FIG. 2 illustrates a solar cell module according to an embodiment of the present invention.

As an example, the solar cell module comprises a front side glass 3, a front side encapsulation material 4, a plurality of cells 5, a back side encapsulation material formed of the non-woven fabric layer 1 and the encapsulation material layer 2, and a back side glass or a back panel 6.

10

The inventors have found that, by a series of tests, the back side encapsulation material layer of the solar cell module which comprises the non-woven fabric layer exhibited even better adhesive force compared with the back side encapsulation material in the prior art. Additionally, upon aging, the power attenuation level of the solar cell module of the present invention was similar to the power attenuation levels of the solar cell modules in the prior art.

15

Examples

The objectives and advantages of the present invention will be further described by examples below. However, the particular materials and the quantities thereof, as well as other conditions and particulars disclosed in the examples, should not be construed as limiting the present invention.

20

Adhesive Strength Test of the Encapsulation Material

Materials for the Test Sample

Materials	Supplier	Features
Non-woven fabric layer A	Zhejiang Yongguang Non-woven Lining Co., Ltd	Dacron non-woven fabric, gram weight: 5 g/m ² ; permeability: 11,000 L/m ² /s
Non-woven fabric layer B	Zhejiang Yongguang Non-woven Lining Co., Ltd	Dacron non-woven fabric, gram weight: 100 g/m ² ; permeability: 710 L/m ² /s
Non-woven fabric layer C	Zhejiang Yongguang Non-woven Lining Co.,	Dacron non-woven fabric, gram weight: 30 g/m ² ;

	Ltd	permeability: 2,914 L/m ² /s
Glass	Nanjing Zhongyu Solar Glass Technology Co., Ltd	Super white patterned glass for solar cell (10 cm × 10 cm)
Encapsulation Material Layer	White EVA, 3M	Gram weight: 405 g/m ² ; reflectivity: 60%
Back panel	3M SF 15T	Fluorine-containing back panel for solar cell

Method of preparing the test sample

The back plate, the white EVA, the non-woven fabric layer and the glass (with the patterned surface of the glass facing the non-woven fabric layer) were put in order from top to bottom into a laminating machine and laminated under the conditions where the temperature was about 145°C, the laminating machine was purged for 5 minutes and the lamination was cured for 13 minutes to form a lamination sample. The temperature of the lamination sample was decreased upon formation thereof and ready for use.

The comparative sample was prepared without the non-woven fabric layer and the comparative sample comprised only the back panel, the white EVA and the glass.

Test methods

Pressure Cooking Test (PCT)

The adhesive force of the test sample upon aging was tested by a Pressure Cooking Test. The test was performed using a “PCT high pressure aging acceleration test machine” manufactured by Dongguan Hongjin Test Instruments Co., Ltd. For each test, the temperature was set at about 120°C, and the pressure was set at 1 standard atmosphere + 0.09 to 0.11 MPa. After the PCT test was completed, the adhesive strength of the glass with respect to the 180° peel force was measured according to the “Standard Test Process for Adhesive Peel or Pull off Strength” (ASTM D903-98, American Society for Testing Materials).

As shown in Table 1-1 to Table 1-3 below, after the PCT aging test, the adhesive strength of the encapsulation material of the present invention was greater than the adhesive strength of the encapsulation material available from the market.

Table 1-1: The Adhesive Strength of the Non-woven Fabric Layer A (Dacron Non-woven Fabric, Gram Weight: 5 g/m²; Permeability: 11,000 L/m²/s) plus EVA with Respect to Glass upon PCT, 96 Hours (N/mm)

	Contrast Sample	Non-woven Fabric Layer A + EVA
Test Value 1	0.199	0.896
Test Value 2	0.372	0.769
Test Value 3	0.286	0.881
Average	0.285666667	0.849

5 Table 1-2: The Adhesive Strength of the Non-woven Fabric Layer B (Dacron Non-woven Fabric, Gram Weight: 100 g/m²; Permeability: 710 L/m²/s) plus EVA with Respect to Glass upon PCT, 96 Hours (N/mm)

	Contrast Sample	Non-woven Fabric Layer B + EVA
Test Value 1	0.199	1.146
Test Value 2	0.372	1.292
Test Value 3	0.286	1.204
Average	0.285666667	1.214

10 Table 1-3: The Adhesive Strength of the Non-woven Fabric Layer C (Dacron Non-woven Fabric, Gram Weight: 30 g/m²; Permeability: 2,914 L/m²/s) plus EVA with Respect to Glass upon PCT, 96 Hours (N/mm)

	Contrast Sample	Non-woven Fabric Layer C + EVA
Test Value 1	0.199	1.294
Test Value 2	0.372	1.308
Test Value 3	0.286	1.247
Average	0.285666667	1.283

Output Power Test of the Solar cell module

Materials for the Test Sample

Materials	Supplier	Features
Front Side Glass	Nanjing Zhongyu Solar Glass Technology Co., Ltd	Super white patterned glass for solar cell (30 cm×30 cm)
Front Side Encapsulation Material	3M EVA 9000	Gram Weight: 405 g/m ² ; Transmittance: 91%
Cell A	Jing Ao Solar Energy Co., Ltd	Model No.: 125SLR22B-002

Cell B	Motech (Suzhou) New Energy Co., Ltd	Model No.: IM156
Non-woven fabric layer D	Shandong Kangjie Non-Woven Fabrics Co., Ltd	Polypropylene Non-woven Fabric, Gram Weight: 20 g/m ²
Non-woven fabric layer E	Zhejiang Yongguang Non-woven Lining Co., Ltd	Polyethylene terephthalate Non-woven Fabric, Gram Weight: 30 g/m ²
Non-woven fabric layer F	Shandong Kangjie Non-Woven Fabric Co., Ltd	Polypropylene Non-woven Fabric, Gram Weight: 15 g/m ²
Back Side Encapsulation Material	3M White EVA	Gram Weight: 405 g/m ² ; Reflectivity: 60% (3M EVA 9000 with high reflection fillers)
Back Side Glass	Nanjing Zhongyu Solar Glass Technology Co., Ltd	Super white patterned glass for solar cell (30 cm × 30 cm)

Method for Preparing the Test Sample

Four pieces of cells were welded in series, and the front side glass, the front side EVA, the welded cells, the non-woven fabric layer, the back side EVA and the back side glass were put in order from top to bottom into a laminating machine and laminated under the conditions where the temperature was about 145°C, the laminating machine was purged for 5 minutes and the lamination was cured for 13 minutes to form a lamination. The temperature of the lamination sample was decreased upon formation thereof and ready for use.

A contrast sample was prepared by using a transparent EVA to replace the non-woven fabric layer to avoid overflow of the encapsulation material, i.e. the contrast sample comprises merely the front side glass, the front side EVA, the cells, the back side transparent EVA, the back side white EVA and the back side glass.

Test methods

Damp Heat (DH) Test

In the damp heat aging test, the aging conditions were set according to IEC6164610.13. The power measurement instrument was Spire solar simulator with a model no. SPI-SUN SIMULATOR 4600 SLP. The measured data is listed in the Table 2 below.

Table 2: DH Aging Test (Cell A)

	Initial Max. Power $P_{\max}$ (W)	Output Power after DH 1,000 Hours
Contrast Sample	9.662	9.379
Non-woven fabric layer D (20 gsm) + EVA	9.647	9.466
	Initial Max. Power $P_{\max}$ (W)	Output Power after DH 2,000 Hours
Contrast Sample	9.418	8.920
Non-woven fabric layer E (30 gsm) + EVA	9.874	9.258

Thermal Cycle (TC) Test

In the thermal cycle (TC) aging test, the aging conditions were set according to

- 5 IEC6164610.11. The power measurement instrument was Spire solar simulator with a model no. SPI-SUN SIMULATOR 4600 SLP. The measured data is listed in the Table 3 below.

Table 3: TC Aging Test (Cell B)

	Initial Max. Power $P_{\max}$ (W)	Output Power after two Hundred Cycles of TC 200 (W)
Contrast Sample	13.303	13.057
Non-woven fabric layer F (15 gsm) + EVA	13.131	12.928

10 Humidity Freeze (HF) Test

In the HF aging test, the aging conditions were set according to IEC6164610.12. The power measurement instrument was Spire solar simulator with a model no. SPI-SUN SIMULATOR 4600 SLP. The measured data is listed in the Table 4 below.

15 Table 4: HF Aging Test (Cell B)

	Initial Max. Power $P_{\max}$ (W)	Output Power in HF 25 Days (W)
Contrast Sample	12.661	12.517
Non-woven fabric layer F (15 gsm) + EVA	12.763	12.608

The above tests proved that the output power of the solar cell module of the present invention upon aging was nearly the same with the output power of the conventional solar cell module.

5 Power and Overflow Tests

Materials for Test Sample

Materials	Supplier	Characteristics
The Front Side Glass	Nanjing Zhongyu Solar Glass Technology Co., Ltd	Super white patterned glass for solar cell (30 cm × 30 cm)
The Front Side Encapsulation Material	3M EVA 9000	Gram Weight: 405 g/m ² ; Transmittance: 91%
Cell A	Jing Ao Solar Energy Co., Ltd	Model No.: 125SLR22B-002
Non-woven fabric layer G	Zhejiang Yongguang Non-woven Lining Co., Ltd	Dacron Non-woven Fabric, Gram Weight: 15 g/m ²
The Back Side Encapsulation Material	3M White EVA	Gram Weight: 405 g/m ² ; Reflectivity: 60%
The Back Side Glass	Nanjing Zhongyu Solar Glass Technology Co., Ltd	Super white patterned glass for solar cell (30 cm × 30 cm)

Method for Preparing the Test Sample

Four pieces of cells are welded in series, and the front side glass, the front side EVA, the welded cells, the non-woven fabric layer, the back side EVA and the back side glass were put in order from top to bottom into a laminating machine and laminated under the conditions where the temperature was about 145°C, the laminating machine was purged for 5 minutes and the lamination was cured for 13 minutes to form a lamination sample. The temperature of the lamination sample was decreased and ready for use.

A contrast sample was prepared without the non-woven fabric layer, i.e. the contrast sample comprised merely the front side glass, the front side EVA, the cells, the back side white EVA and the back side glass.

Test Methods

The power measurement instrument was Spire solar simulator with a model no. SPI-SUN SIMULATOR 4600 SLP. The measured data is listed in Table 5 below.

Table 5: Power and Overflow Tests

	$P_{\max}$ (W)	Appearance
Non-woven fabric layer G (15 g/m ²) + EVA	10.375	No overflow
Contrast Sample	10.279	Overflow

The test results showed that, by using the encapsulation material of the present invention, the overflow issue could be effectively avoided, and the actual power of the solar cell module using the encapsulation material of the present invention was greater than that of the solar cell module manufactured by the conventional technology.

It can be seen from the above tests that the encapsulation material prepared by using a non-woven fabric layer and a white EVA layer can achieve substantially the same initial maximal power and power attenuation compared with the conventional EVA encapsulation material. The tests also have indicated that, although it was prone to overflow in the laminating process without a non-woven fabric layer and a white and transparent EVA, the combination of the PP or PET non-woven fabric layer and the white EVA did not overflow in the laminating process and the post-laminating process. Therefore, the encapsulation material according to the present invention can be widely used in current commercially available solar cells to avoid the overflow issue without decreasing the efficiency of the solar cells. The encapsulation material according to the present invention can be made in relatively low costs, and accordingly exhibits a very good cost performance.

Adhesion to glass

The adhesion of white EVA to solar glass was measured immediately after application and after exposure to ten humidity-freeze cycles conducted according to IEC6164610.12. Bonding strength was measured according to ASTM D903. The initial bonding strength was 7.6 N/mm, and the bonding strength after ten humidity-freeze cycles was about 7.5 N/mm, demonstrating the durability of the adhesion despite the environmental challenge. Interlayer delamination of the white EVA was observed (FIG. 3), with delamination occurring at a bonding strength of about 9.5 N/mm.

White EVA penetration of nonwoven fabric

Because adhesion to the PV cells depends on the penetration of the nonwoven fabric by the white EVA during the lamination process, the ability of white EVA to penetrate the nonwoven fabric and provide adequate adhesion was examined. Surface flat solar glass was substituted for PV cells. In a laminating machine, the surface flat solar glass, polypropylene nonwoven fabric, and white EVA were laminated together in that order. Bonding strength was measured as laminated (initial value) and after a sample was subjected to the pressure cooker test (described above) for 24 hours (PCT24). The initial value of the bonding strength was 2.5 N/mm and the PCT24 value was 2.0 N/mm. As can be seen in FIG. 4, the white EVA was able to penetrate the polypropylene nonwoven fabric and bond to the glass, demonstrating good bonding strength both initially and after the 24 hour pressure cooker test.

It will be understood that, to a person skilled in the art, there apparently exist various alterations or modifications to the embodiments as described above. Such alterations and modifications will fall within the scope of the appended claims.

What is claimed is:

1. An encapsulation material for a solar cell, characterized in that the encapsulation material comprises an encapsulation material layer (2) and a non-woven fabric layer (1), wherein the
5 non-woven fabric layer (1) has a gram weight of 5 to 100 g/m² and a permeability of 710 to 11,000 L/m²/s.
2. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) has a gram weight of 10 to 70 g/m² and a permeability of 1,000 to
10 6,500 L/m²/s.
3. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) has a gram weight of 5 g/m² and a permeability of 11,000 L/m²/s.
- 15 4. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) has a gram weight of 100 g/m² and a permeability of 710 L/m²/s.
5. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) has a gram weight of 30 g/m² and a permeability of 2,914 L/m²/s.
20
6. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) is disposed on the encapsulation material layer (2), or enters partially or completely the encapsulation material layer (2).
- 25 7. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) is formed of a fiber material or a slice material.
8. The encapsulation material for a solar cell according to claim 7, characterized in that the fiber material includes a natural fiber, a regenerated fiber, a synthetic fiber or an inorganic fiber.
30

9. The encapsulation material for a solar cell according to claim 8, characterized in that the natural fiber includes a cotton fiber, a linen fiber, a wool or a silk.

10. The encapsulation material for a solar cell according to claim 8, characterized in that the regenerated fiber includes a bamboo fiber, a soybean fiber, a tencel fiber, a modal fiber or a polylactic acid fiber.

11. The encapsulation material for a solar cell according to claim 8, characterized in that the synthetic fiber includes a polypropylene fiber, a polyester fiber, a polyacrylonitrile fiber, a bicomponent fiber, a nylon fiber, a polyethylene fiber, a rayon fiber, a polyurethane fiber, or a mixture of two or more of the above polymer fibers.

12. The encapsulation material for a solar cell according to claim 8, characterized in that the inorganic fiber includes a ceramic fiber, a boron fiber, a metal fiber or a carbon fiber.

13. The encapsulation material for a solar cell according to claim 7, characterized in that the slice material includes polyethylene, polypropylene, polyester or nylon.

14. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) comprises a short fiber having a length of 10 to 100 mm and a fiber fineness of 0.5 to 100 D.

15. The encapsulation material for a solar cell according to claim 1, characterized in that the non-woven fabric layer (1) comprises a short fiber having a length of 38 to 76 mm and a fiber fineness of 1.5 to 15 D.

16. The encapsulation material for a solar cell according to claim 11, characterized in that the short fiber of the non-woven fabric layer (1) has a cross section in a circular or an irregular shape.

17. The encapsulation material for a solar cell according to claim 1, characterized in that the encapsulation material layer (2) comprises an ethylene-vinyl acetate copolymer, a polyolefin copolymer, or a mixture of several different polymers.

18. The encapsulation material for a solar cell according to claim 1, characterized in that the encapsulation material layer (2) has a complex viscosity of 80 Pa*s to 154,000 Pa*s under conditions where the shear frequency is 0.0158 Hz and the temperature is 120°C.

19. The encapsulation material for a solar cell according to claim 1, characterized in that the encapsulation material layer (2) has a complex viscosity of 54 Pa*s to 1,117 Pa*s under conditions where the shear frequency is 39.8 Hz and the temperature is 120°C.

20. The encapsulation material for a solar cell according to claim 1, characterized in that the encapsulation material layer (2) comprises a high reflectivity encapsulation material or a low transmittance encapsulation material.

21. The encapsulation material for a solar cell according to claim 20, characterized in that the transmittance of the encapsulation material layer (2) is smaller than 80%.

22. The encapsulation material for a solar cell according to claim 1, characterized in that the encapsulation material layer (2) includes a white encapsulation material, a translucent encapsulation material, or a color encapsulation material.

23. A solar cell module, characterized in that the solar cell module comprises a plurality of cells (5) and a back side glass attached to the cells (5) using the encapsulation material according to any one of claims 1 to 22, wherein the non-woven fabric layer (1) is disposed facing the cells (5).

24. A solar cell module, characterized in that the solar cell module comprises a plurality of cells (5) and a back panel attached to the cells (5) using the encapsulation material according to any one of claims 1 to 22, wherein the non-woven fabric layer (1) is disposed facing the cells (5).

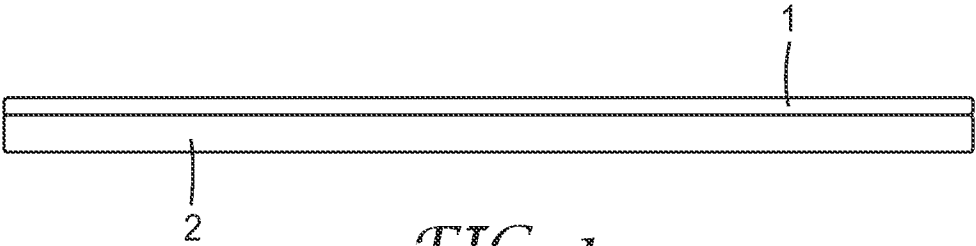


FIG. 1

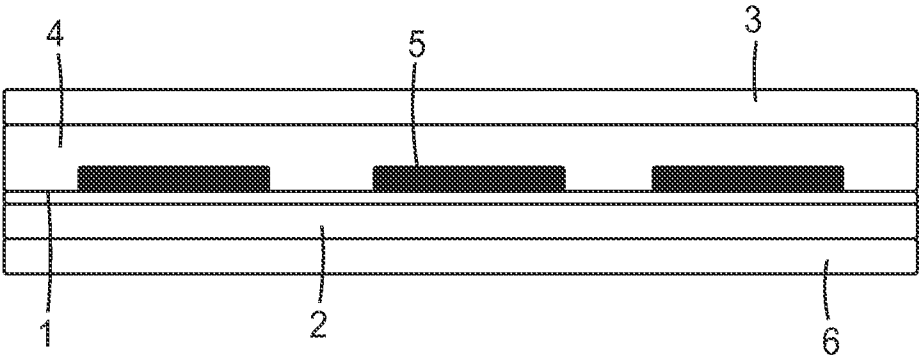


FIG. 2

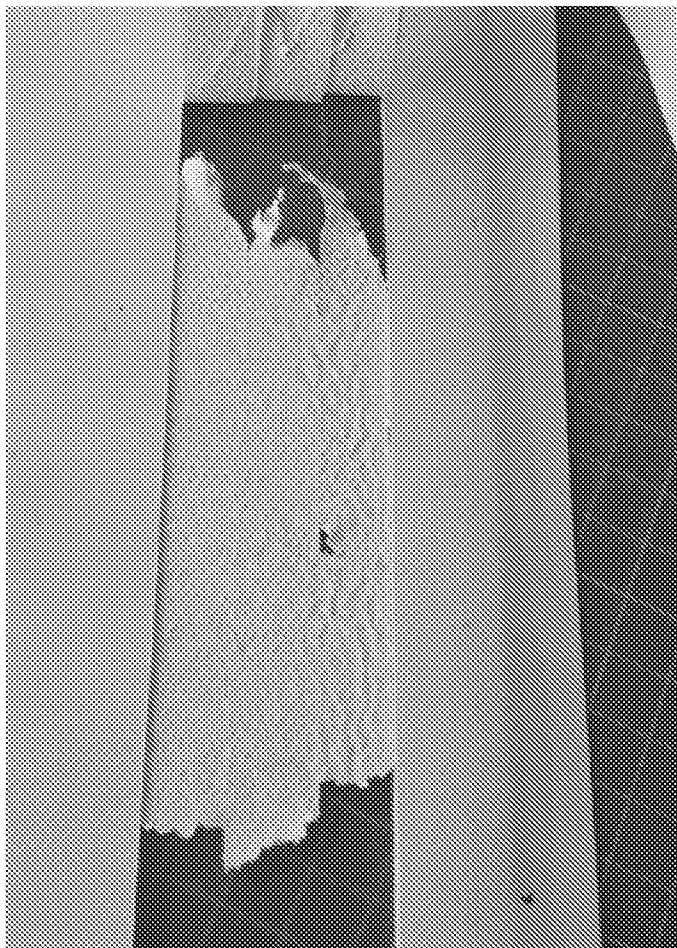


FIG. 3

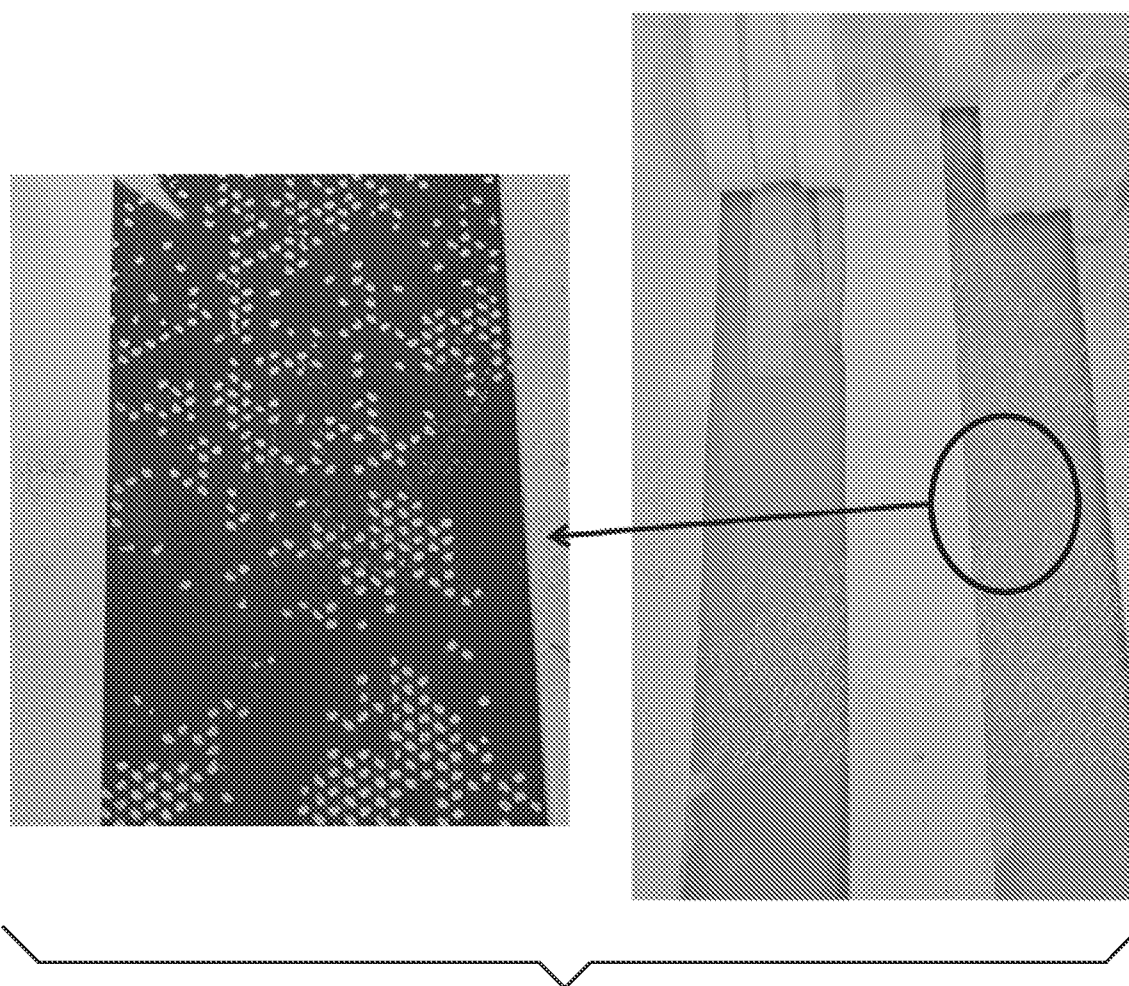


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/49862

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H01L 31/048, 31/042, 31/053 (2014.01)

CPC - H01L 31/048, 31/042, 31/0424, 31/02008; Y02E 10/50

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)

IPC(8): H01L 31/048, 31/042, 31/053 (2014.01)

CPC: H01L 31/048, 31/042, 31/0424, 31/02008; Y02E 10/50; Y02B10/10; USPC: 136/251, 244, 252, 259; 438/66; 257/433

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)

MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); ProQuest; IP.com; Google/Google Scholar; Key Words: solar cell*, module, encapsulat*, enclos*, cover*, layer*, non*woven, fabric*, weight, capacity, permeability, fiber*, fibre*, inorganic, regenerate*, natural, synethetic, glass, ceramic, cotton, bamboo, polypropylene, length, long, fineness, denier, viscosity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,800,631 A (YAMADA, S et al.) 01 September 1998; abstract; column 6, lines 51-58; column 10, lines 36-40; column 14, lines 5-10; column 19, lines 53-54; column 20, lines 58-67; column 21, lines 10-13; column 20, lines 10-11, 40-42; column 21, lines 10-13; column 22, lines 40-42; column 30, lines 5-10, 17-18; column 31, lines 3-6; figures 1B; 5; claim 2	1-22, 23/1-22, 24/1-22
Y	US 6,395,046 B1 (EMIG, D et al.) 28 May 2002; column 4, lines 66-67; column 5, lines 1-3	1-22, 23/1-22, 24/1-22
Y	CN 102848680 A (HUANG, H) 02 January 2013; see translation; abstract; claim 1	9-10, 23/9-10, 24/9-10
Y	US 6,420,645 B1 (OHTSUKA, T et al.) 16 July 2002; column 4, lines 3-8, 19-24; column 17, lines 15-20	12, 22, 23/12, 23/22, 24/12, 24/22
Y	CN 1242104 C (CHENG, B et al.) 15 February 2006; see translation; abstract; claim 1	13, 23/13, 24/13
Y	US 2010/0180558 A1 (ITO, M et al.) 22 July 2010; paragraph [0025]	14-15, 23/14-15, 24/14-15
Y	US 2012/0000514 A1 (AMAMIYA, T et al.) 05 January 2012; abstract; paragraph [0189]; claims 1, 10	18-19, 23/1-22, 24/18-19
Y	WO 2012091068 A1 (FUNAYAMA, K et al.) 05 July 2012; page 9, lines 10-20	20-21, 23/20-21, 24/20-21
Y	US 2012/0222726 A1 (QIN, H et al.) 06 September 2012; abstract; paragraph [0054]	24/1-22



Further documents are listed in the continuation of Box C.



* Special categories of cited documents:

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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

24 September 2014 (24.09.2014)

Date of mailing of the international search report

27 OCT 2014

Name and mailing address of the ISA/US

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Authorized officer:

Shane Thomas

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/49862

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,127,622 A (YAMADA, S et al.) 03 October 2000; entire document	1-22, 23/1-22, 24/1-22
A	US 2004/0229404 A1 (KISO, S et al.) 18 November 2004; entire document	1-22, 23/1-22, 24/1-22
A	US 2011/0011457 A1 (SPORTEL, EP et al.) 20 January 2011; entire document	1-22, 23/1-22, 24/1-22