

An improved photovoltaic deviceTechnical Field

The present invention relates to an improved photovoltaic device.

5 Background

Photovoltaic (PV) devices are generally installed at rooftops. However, in order to obtain maximise use, it would be advantageous to use PV devices on outer walls of buildings to efficiently use solar light.

While having PV devices on outer walls of buildings would be advantageous, this is not
10 commonly being done. One of the reasons for this is because installing traditional PV devices on the outer wall would interfere with the aesthetics of the building. It is therefore required for a PV device having a building integrated structure to have excellent aesthetic properties which is able to blend in with the overall look of the building.

15 Coloured solar panels are known in the art in which a coloured layer or coloured film is provided over the PV device. However, the amount of light incident to the solar cell comprised in the PV device may be reduced, and thus the output of the PV device may be reduced. Further, it may be difficult to realise a colour, pattern and/or texture to make the PV device blend with the rest of the building on which it is used, while
20 maintaining efficiency of the PV device. Currently, it may be possible to obtain a specific pattern but this comes at the expense of power loss.

There is therefore a need for an improved PV device which may be suitably used as a building integrated photovoltaic (BIPV) module while minimising loss on the PV device's power efficiency.

25 Summary of the invention

The present invention seeks to address these problems, and/or to provide an improved PV device.

According to a first aspect, the present invention provides a photovoltaic (PV) device comprising:

30 - a solar cell;

- a sealing member for sealing the solar cell;
- a first cover member disposed on the sealing member at one side of the solar cell;
- a second cover member disposed on the sealing member at another side of the solar cell;
- a non-homogeneous pattern layer for providing a patterned PV device, the non-homogeneous pattern layer provided on or adjacent a surface of the solar cell; and
- a homogeneous base layer adjacent the non-homogeneous pattern layer, the homogeneous base layer being closer to the solar cell as compared to the non-homogeneous pattern layer.

The non-homogeneous pattern layer may be provided on a surface of the first cover member or on a surface of the sealing member adjacent the first cover member. In particular, the non-homogeneous pattern layer may be provided on a surface of the first cover member facing the sealing member.

The non-homogeneous pattern layer may be formed by any suitable method. For example, the non-homogeneous pattern layer may be formed by, but not limited to: screen printing, digital printing, frit printing or a combination thereof.

According to a particular aspect, the homogeneous base layer may be provided on a surface of the sealing member.

The homogeneous base layer may be formed by any suitable method. For example, the homogeneous base layer may be formed by, but not limited to: interference coating, sputter coating, scattering, or a combination thereof. In particular, the homogeneous base layer may comprise spectrally selective reflective material.

The first cover member may be of any suitable material. For example, the first cover member may comprise, but is not limited to: glass, thermoplastic polymer, poly(methyl methacrylate), polycarbonate, or a combination thereof.

The solar cell comprised in the PV device may be any suitable solar cell. For example, the solar cell may comprise, but is not limited to: perovskite solar cell, copper indium

gallium selenide (CIGS) solar cell, copper indium gallium selenide selenium (CIGSSe) solar cell, silicon solar cell, or a combination thereof.

The present invention also provides a building-integrated photovoltaic (BIPV) module comprising a PV device according to the first aspect.

5 Brief Description of the Drawings

In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments, the description being with reference to the accompanying illustrative drawings. In the drawings:

- 10 Figure 1 shows a schematic representation of the PV device according to one embodiment of the present invention;

Figure 2 shows a schematic representation of the PV device according to one embodiment of the present invention; and

- 15 Figure 3 shows an example of the look of a non-homogeneous pattern layer and a homogeneous base layer of a PV device according to one embodiment of the present invention.

Detailed Description

As explained above, there is a need for an improved photovoltaic (PV) device which may be comprised in building-integrated photovoltaic (BIPV) modules.

- 20 In general terms, the invention relates to a PV device for use in a BIPV module that may enable the BIPV module to emulate the aesthetic of building material. The PV device may therefore emulate the look and feel of various building materials while minimising power loss.

- 25 According to a first aspect, the present invention provides a photovoltaic (PV) device comprising:

- a solar cell;
- a sealing member for sealing the solar cell;

- a first cover member disposed on the sealing member at one side of the solar cell;
- a second cover member disposed on the sealing member at another side of the solar cell;
- 5 - a non-homogeneous pattern layer for providing a patterned PV device, the non-homogeneous pattern layer provided on or adjacent a surface of the solar cell; and
- 10 - a homogeneous base layer adjacent the non-homogeneous pattern layer, the homogeneous base layer being closer to the solar cell as compared to the non-homogeneous pattern layer.

The combination of the non-homogeneous pattern layer and the homogeneous base layer enable PV devices of different BIPV module designs. For example, the non-homogeneous pattern layer may serve as the pattern layer providing different patterns and designs. The homogeneous base layer may serve as the base colour layer, thereby providing any aesthetic as required.

A schematic representation of a PV device according to one embodiment of the present invention is provided in Figure 1. However, Figure 1 is not intended to be limiting on the present invention and it would be understood that other arrangements may be included within the scope of the invention.

Figure 1 provides a PV device 100 comprising a first cover member 102, a sealing member 104a and 104b, a solar cell 106, and a second cover member 108. The sealing member 104a and 104b surround and seal the solar cell 106. The first cover member 102 may be positioned at a surface, for example a front surface, of the solar cell 106 on the sealing member 104a, and a second cover member 108 may be positioned at the other surface, for example a back surface, of the solar cell 106 on the sealing member 104b.

The non-homogeneous pattern layer may be provided on a surface of the first cover member or on a surface of the sealing member adjacent the first cover member. In particular, the non-homogeneous pattern layer may be provided on a surface of the first cover member facing the sealing member. With reference to Figure 1, the first cover member 102 may comprise a non-homogeneous pattern layer while the sealing

member 104a may comprise a homogeneous base layer. In particular, the non-homogeneous pattern layer may be provided on a surface of the first cover member facing the sealing member 104a. However, as mentioned above, the non-homogeneous pattern layer need not be comprised in the first cover member 102 and
5 may instead be provided on a surface of the sealing member 104a or as a distinct separate layer anywhere above the solar cell 106.

The non-homogeneous pattern layer may be formed by any suitable method. According to a particular aspect, the non-homogeneous pattern layer may be formed by a printing process. In particular, the printing process may comprise screen printing,
10 digital printing, frit printing, or a combination thereof. For example, the printing process may comprise, but is not limited to: screen printing, inkjet printing, lithography printing, laser printing, frit printing or a combination thereof. The inkjet printing may be digital inject printing.

According to a particular aspect, the non-homogeneous pattern layer may be formed
15 so that the PV device 100 has one or more of a desired colour, image, pattern, feeling, texture, and the like. In particular, to achieve a desired colour and/or pattern, printing using a colouring material may be performed to form the non-homogeneous pattern layer. The colouring material may comprise, but is not limited to, a ceramic frit, colour pigment, enamel ink, dye, or a combination thereof. The colouring material may be
20 selected to reflect and/or absorb certain wavelength of light. In particular, the perceived colour obtained may be due to the reflected light.

According to a particular aspect, the homogeneous base layer may be provided adjacent the non-homogeneous pattern layer such that the homogeneous base layer is below the non-homogeneous pattern layer. The homogeneous base layer may be
25 provided on a surface of the sealing member. Alternatively, the homogeneous base layer may be provided as a distinct separate layer above the solar cell 106.

The homogeneous base layer may be formed by any suitable method. For example, the homogeneous base layer may be formed by, but not limited to: interference coating, sputter coating, scattering, or a combination thereof. In particular, the
30 homogeneous base layer may comprise spectrally selective reflective material. The spectrally selective reflective material may be in the form of a photonic structures, crystals or particles provided on the sealing member 104a. The spectrally selective

reflective material may be deposited on the surface through any suitable method. According to a particular aspect, the spectrally selective reflective material may be mixed with the material from which the sealing member is formed such that the homogeneous base layer is formed on or within the sealing member.

- 5 The homogeneous base layer may function as an additional colour layer. In particular, the homogeneous base layer may selectively reflect wavelength of interest with minimal absorption and therefore able to provide a colour of interest at minimal power loss. Even more in particular, the spectrally selective reflective material comprised in the homogeneous base layer selectively reflects specific wavelength of light to achieve
10 a specific colour.

According to a particular aspect, the non-homogeneous pattern layer may be provided on a smaller surface area as compared to the homogeneous base layer.

- Overall, the colouring material comprised in the non-homogeneous pattern layer may result in reduction of efficiency of the PV device in the form of power loss due to the
15 combined effects of reflection and absorption of light by the colouring material. However, in the present invention, the PV device is able to achieve a suitable efficiency while still maintaining the desired pattern and colour due to the provision of the non-homogeneous pattern layer and homogeneous base layer, respectively. In particular, the non-homogeneous pattern layer provides the desired pattern and/or design with
20 minimal coverage as a non-homogeneous layer while the homogeneous base layer provides the desired colour with full coverage as a homogeneous layer. Even more in particular, the non-homogeneous pattern layer formed by printing has more power loss but a high range of aesthetic flexibility, while the homogeneous base layer formed by spectrally selective reflective material has minimal power loss but less flexibility in
25 terms of aesthetics. However, since the area on which the non-homogeneous pattern layer is formed is much smaller as compared to the homogeneous base layer, the overall power loss is reduced while being able to achieve the desired aesthetic of the PV device.

- According to a particular aspect, the PV device according to the present invention
30 comprises patterning with only small coverage and a spectrally selective reflective filter which selectively reflects light (colour of interest) as a homogeneous base colour layer to achieve the desired aesthetic with minimal power loss.

The first cover member 102 and the second cover member 108 may be of any suitable material. The first cover member 102 and the second cover member 108 may be formed of an insulating material capable of protecting the solar cell 106 from external impact, moisture, ultraviolet rays, and the like.

- 5 The first cover member 102 and the second cover member 108 may have a pre-determined structure so that the PV device 100 has a desired appearance such as a pre-determined colour, image, pattern, feeling, texture, and the like.

The first cover member 102 may have light transmitting property that allows light to pass therethrough so as not to block the light incident on the solar cell 106. The first
10 cover member 102 may be a substrate, a film, a sheet, panel, or the like. The first cover member 102 may comprise, but is not limited to: glass, thermoplastic polymer, poly(methyl methacrylate), polycarbonate, or a combination thereof. In particular, the first cover member 102 is made of glass.

The second cover member 108 may have excellent fire resistance and insulating
15 properties. For example, the second cover member 108 may be a substrate, a film, a sheet, panel or the like and may be formed of, but not limited to: glass, thermoplastic polymer, poly(methyl methacrylate), polycarbonate, or a combination thereof.

The solar cell comprised in the PV device may be any suitable solar cell. The solar cell may have any suitable structure. For example, the solar cell may be a compound
20 semiconductor solar cell, a thin-film semiconductor solar cell, a dye-sensitized solar cell, or a combination thereof. According to a particular aspect, the solar cell may comprise, but is not limited to: perovskite solar cell, copper indium gallium selenide (CIGS) solar cell, copper indium gallium selenide selenium (CIGSSe) solar cell, silicon solar cell, or a combination thereof.

- 25 The solar cell may include a photoelectric conversion portion that converts solar energy into electrical energy, and an electrode that is electrically connected to the photoelectric conversion portion and collects and transfers an electric current. For example, the solar cell may be a solar cell that generates electrical energy from light of a wavelength of 100-1400 nm.

According to a particular aspect, the solar cell may comprise one or more solar cells. When the solar cell comprises a plurality of solar cells, each solar cell of the plurality of solar cells may be electrically connected in series, parallel or series-parallel.

5 The sealing member may comprise a first sealing member 104a positioned on the front surface of the solar cell 106 and a second sealing member 104b positioned on the back surface of the solar cell 106. The first sealing member 104a and the second sealing member 104b may prevent moisture and oxygen from entering and chemically bind to the solar cell 106.

10 The first sealing member 104a and the second sealing member 104b may be formed of any suitable material. For example, the first sealing member 104a and the second sealing member 104b may be formed of an insulating material having translucency and adhesiveness. Suitable materials for the first sealing member 104a and the second sealing member 104b include, but is not limited to, ethylene-vinyl acetate copolymer resin (EVA), a polyvinyl butyral, silicone resin, ester resin, olefin resin, or a combination
15 thereof.

Another embodiment of the present invention comprises a conventional PV device 200 (Figure 2) comprising a first cover member 202, a sealing member 204a and 204b, a solar cell 206, a second cover member 208, a non-homogeneous pattern layer 210 and a homogeneous base layer 212. The non-homogeneous pattern layer 210 and the
20 homogeneous base layer 212 may be as described above in relation to non-homogeneous pattern layer comprised in the cover member 102 and a homogeneous base layer comprised in the sealing member 104a above.

According to a second aspect, there is also provided a building-integrated photovoltaic (BIPV) module comprising a PV device according to the first aspect.

25 Having now generally described the invention, the same will be more readily understood through reference to the following embodiment which is provided by way of illustration, and is not intended to be limiting.

Example

Two sets of PV patterned devices were prepared – a digitally printed conventional PV device and the other PV device comprised a non-homogeneous pattern layer and a homogeneous base layer. The methods to prepare the PV devices were as follows.

Conventional PV device

- 5 A design/pattern was created using an imaging software and subsequently the design/pattern was printed in a glass substrate. The printed glass substrate formed the first cover member and was placed above a solar cell encapsulated in a sealing member to form the conventional PV device. The electrical performance of the conventional PV device was measured with a solar simulator under standard test
10 conditions (STC).

PV device comprising non-homogeneous pattern layer and a homogeneous base layer

- A design/pattern was created using an imaging software. In particular, a homogeneous pattern layer was digitally printed on a surface of a glass substrate forming the first cover member. The sealing member was deposited with photonic structure such that
15 the sealing member in contact with the top surface of the solar cell formed the homogeneous base layer. The printed glass substrate formed the first cover member and was placed above a solar cell encapsulated in a sealing member comprising the homogeneous base layer to form the PV device according to the present invention (termed "hybrid PV device"). In this manner, two PV devices were formed, one having
20 a pattern mimicking a concrete look and the other having a geometrical pattern. Figure 3 illustrates the look of the non-homogeneous pattern layer and the homogeneous base layer.

The electrical performance of the hybrid PV devices were measured with a solar simulator under standard test conditions (STC).

- 25 The results of the electrical performances are shown in Table 1.

Design	Technology	Normalized I_{sc}	ΔI_{sc} [%]
Standard	-	0.918	-
Concrete	Full digital printing	0.613	-33.2
	Hybrid	0.680	-25.9
Geometry	Full digital printing	0.640	-30.3
	Hybrid	0.677	-26.3

Table 1: Results of electrical performance of PV devices formed using different methods

From the short circuit current of the PV devices measured against a standard PV
 5 module with transparent glass, it can be seen that for the concrete and geometry
 designs, the power loss of the hybrid PV devices were lower than the fully digitally
 printed PV devices. In fact, there was a 4-7% improvement in power for the concrete
 and geometry designs.

Whilst the foregoing description has described exemplary embodiments, it will be
 10 understood by those skilled in the technology concerned that many variations may be
 made without departing from the present invention.