

## ***Solar Cell Assembly***

### ***Field of the Invention***

The present invention relates to solar cell assemblies and particularly, although not exclusively,  
5 to solar cell assemblies using a foil-wire electrode assembly for connection of solar cells within  
the assembly.

### ***Background***

Solar modules for providing electrical energy from sunlight comprise an array of cells, each  
10 comprising a photovoltaic element, or substrate. The solar cells are typically connected so that  
electrical current is routed, via an electrical connector, from a front surface of one solar cell to a  
back/rear surface of a second solar cell, or vice versa. Each of the electrical connectors  
comprises a plurality of electrically conductive elements (e.g. interconnecting wires) which form  
an electrical connection with electrodes arranged on the respective front and rear surfaces of  
15 the solar cells.

A general aim for solar cell development is to attain high conversion efficiency balanced by a  
need for reduced production costs. Efforts to achieve this have focussed on the electrical  
connections between the solar cells.

One approach has been to provide foil-wire electrodes which connect directly to finger  
20 electrodes arranged on the surface of each solar cell. The foil-wire electrodes reduce electrical  
losses by minimizing the impact of cell damage on the performance of the solar module.  
Furthermore, the use of foil-wire electrodes can also lead to a significant reduction in module  
production costs and optical losses arising from the light shading caused by configuring the  
solar cell's surfaces with conventional printed busbar electrodes.

25 However, despite these developments, there remains a desire to further improve both the  
performance and the aesthetic appearance of solar cell assemblies using such foil-wire  
electrode assemblies.

The present invention has been devised in light of the above considerations.

### ***Summary of the Invention***

In known solar cell assemblies incorporating a foil-wire electrode assembly, a plurality of wires  
coated with a low melting point alloy are used to interconnect a plurality of solar cells within the  
assembly. Specifically, the wires connect at least a front surface of a first solar cell in the  
assembly with a rear surface of a second solar cell in the assembly. The wires are positioned in

parallel and laminated on said front or rear surfaces in an over/under pattern. The wires are laminated between said front or rear surfaces and a transparent film, also referred to herein as a 'foil'. Accordingly, each solar cell in the assembly has such a foil disposed on a front and/or a rear surface of the cell. The foils in the solar cell assembly can therefore be split into two

5 nominal groups of foils: front foils, which are disposed on a front face of the solar cell to which they are attached; and rear foils, which are disposed on a rear face of the solar cell to which they are attached. In conventional arrangements, the front and rear foils are identical, and are formed from a transparent insulating film – the use of a transparent film allows for good light transmission to the solar cells in the assembly. Furthermore, the use of transparent film for both

10 the front and rear foils is advantageous as it permits or encourages the passage of light through the film and allows the solar cell assembly to be used bifacially. Furthermore, the use of the same material for both front and rear foils can allow for high manufacturing efficiency.

The term 'foil' as used in the present disclosure (unless indicated otherwise) is a specific term of art, referring to a film, or thin layer of material, the composition of which is not specifically

15 limited. The term 'foil' is not used herein (unless indicated otherwise) to refer only to thin sheet metal, as is one conventional use of the term outside of the technical field of solar cells. Typically the foils of a foil-wire electrode assembly are provided as a plurality of individual and separate foils. However it is also contemplated that in some arrangements, the foils may be provided as a plurality of foil portions defining part of a larger foil. The terms "foil" and "foil

20 portion" are used interchangeably in the foregoing and following disclosure unless explicitly specified otherwise, and so features described in relation to "a foil portion" should be understood as applying equally to "a foil", and vice versa.

The present inventors have realised that by making the front and rear foils different, one or both of the performance and/or the aesthetic appearance of solar cell assemblies using foil-wire

25 electrode assemblies may be improved.

Accordingly, in a general aspect, the present invention provides a solar cell assembly comprising a plurality of solar cells interconnected by a foil-wire electrode assembly, the foil-wire electrode assembly comprising a plurality of conductive elements and a plurality of foil portions including front foil portions laminated on respective front surfaces of the plurality of solar cells,

30 and rear foil portions laminated on respective rear surfaces of the plurality of solar cells, wherein the rear foil portions are different to the front foil portions.

The front surface of the solar cell may define the surface of the solar cell upon which light is incident when the solar cell assembly is in use (e.g. the frontmost surface of the solar cell). The back or rear surface of the solar cell will define the surface of the solar cell which is opposite the

35 front surface (e.g. the backmost surface of the solar cell). The rear surface of the solar cell may not be directly exposed to incident light during use.

The term 'laminated on' is used herein to define an arrangement in which one layer overlies another layer of material. For example, the phrase "a foil portion laminated on a front surface of

a solar cell" can be understood as defining that the foil portion overlies the front surface of the solar cell. The lamination may be direct, or indirect. Where layers are directly laminated on one another, they are in direct contact. Where layers are indirectly laminated on one another, they may not be in direct contact, and may have one or more further layers or other components disposed between the defined layers. The term 'laminated on' is sometimes used in the art to refer to layers that are laminated together via a lamination process including application of heat and/or pressure. However, in the present disclosure the term 'laminated' is not limited only to description of such arrangements. Rather, the term may additionally describe layers that are laminated by being overlaid on one another, or by being attached to one another without necessarily requiring application of heat and/or pressure e.g. via an adhesive. Accordingly, the term 'laminated on' can be used interchangeably with 'disposed on' 'attached to' or 'connected to' as appropriate.

It will be understood that the terms 'conductive' and 'insulating' as used herein, are expressly intended to mean electrically conductive and electrically insulating, respectively. The meaning of these terms will be particularly apparent in view of the technical context of the disclosure, being that of photovoltaic solar cell devices. It will also be understood that the term 'ohmic contact' is intended to mean a non-rectifying electrical junction (i.e. a junction between two conductors which exhibits a substantially linear current-voltage (I-V) characteristic).

The rear foil portions may include or be formed from different materials and/or have different material characteristics to the front foil portions. In this way, the properties of the foils can be suitably tailored to improve either or both of the of the performance and/or the aesthetic appearance of the solar cell assembly.

As mentioned above, foil-wire electrode assemblies are commonly used in combination with solar cells having some level of bifaciality – for example, heterojunction technology (HJT) cells. However, in most typical uses of solar cell assemblies, cells are typically arranged such that in use, the front side of the cell is arranged to face a source of incident light, with the rear side being oppositely disposed to this, facing away from the source of incident light. This means that in order to make use of the bifaciality of the cells, a reflective backsheet must typically be used in the solar cell module. There are disadvantages associated with such arrangements, in that the reflective backsheet can be seen between adjacent cells in the module, or around the periphery of cells in the module, increasing the visual contrast between cells and the backsheet, thereby reducing the aesthetic appeal of the module.

The present inventors have realised that these problems can be reduced or avoided by selecting the reflectance of the front and rear foil portions in a foil-wire electrode assembly to be different: more specifically, by providing rear foil portions having a higher reflectance as compared with the front foil portions.

Accordingly, in a first aspect, the present invention provides a solar cell assembly comprising a plurality of solar cells interconnected by a foil-wire electrode assembly, the foil-wire electrode

assembly comprising a plurality of conductive elements and a plurality of foil portions including front foil portions laminated on respective front surfaces of the plurality of solar cells, and rear foil portions laminated on respective rear surfaces of the plurality of solar cells, wherein the rear foil portions have a higher reflectance than the front foil portions.

- 5 In a second aspect, the present invention provides a foil-wire electrode assembly, the foil-wire electrode assembly comprising a plurality of conductive elements and further comprising a plurality of foil portions including at least one first foil portion and at least one second foil portion, wherein the second foil portion has a higher reflectance than the first foil portion. The at least one first foil portion may be configured to be laminated on a front surface of a solar cell – e.g. by  
10 being configured to permit or encourage the passage of light through the foil, such as by suitable material selection to ensure that the foil is substantially transparent. The at least one second foil portion may be configured to be laminated on a rear surface of a solar cell – e.g. by being configured to permit or encourage reflection of light from the foil, and restrict passage of light through the foil, such as by suitable material selection to ensure that the foil is substantially  
15 reflective. The foil-wire electrode assembly of the second aspect may be suitable for use in forming a solar cell assembly of the first aspect, by arranging it to interconnect a plurality of solar cells.

- Specifically, by providing an arrangement in which rear foil portions of a foil-wire electrode assembly have a higher reflectance than front foil portions of the assembly, it may be possible  
20 to improve efficiency or power generation of a solar cell assembly incorporating the foil-wire electrode assembly, because light incident on a front face of the solar cell which penetrates through the cell may be reflected by the higher-reflectance rear foil, thereby allowing capture of the reflected light by a rear face of the solar cells. This advantage is provided even compared with conventional arrangements in which a high-reflectance backsheet is provided in a solar  
25 module incorporating a conventional solar cell assembly having identical transparent front and rear foils: in such conventional arrangements, because the rear foil of the foil-wire electrode assembly is transparent, light which penetrates the solar cell must travel to reach the high-reflectance backsheet before being reflected. This is a relatively long light path (including at least the thickness of the solar cell, and the rear encapsulant) which can allow for some loss of  
30 light and reduce the total percentage of penetrating light which is reflected back to solar cells in the module. In comparison, in arrangements according to the present invention, a comparatively much shorter light path is provided for reflection of penetrating light, because the higher-reflectance foil layer is provided directly adjacent the solar cells in the assembly. There is no encapsulation layer or similar interposed between the solar cell and the higher-reflectance  
35 foil layer. This shorter light path may allow for reduced loss of reflected penetrating light, and thereby increase the efficiency of the solar cell assembly. The reflectance light path in arrangements according to the present invention may have a length that is no greater than the thickness of the solar cell itself, as the higher-reflectance rear foil is in direct contact with the solar cell.

The present inventors have found that the advantages of the present invention may be particularly apparent for solar cell arrangements having thinner cells (e.g. for cells having a thickness of 120  $\mu\text{m}$  or less) due to the greater amount of light that is able to penetrate through cells of such a thickness as compared with thicker cells, however some benefit may be obtained in solar cell arrangements irrespective of cell thickness.

Arrangements according to the present invention can also offer further advantages in addition to the advantages discussed above relating to improved efficiency of the solar cell assembly: because a higher-reflectance layer is provided to be directly adjacent the solar cells in the module, it is also not necessary to provide a solar module incorporating the solar cell assembly with a high-reflectance backsheet. Instead, a solar module incorporating the solar cell assembly of the present invention can comprise a black, or other dark-colour backsheet. This can reduce visual contrast of the backsheet of the module with the solar cells of the module and thereby allow for an improved aesthetic appearance of the solar module.

The reflectance of the foils may be measured by shining light on a sample and measuring the light reflected from the sample. Reflected light consists of specular reflected light and diffuse reflected light, which when combined together is referred to as total reflected light (specular reflected light plus diffuse reflected light). One suitable method for characterising the reflectance of the foils is measuring the reflectance using reflectance spectroscopy with an integrated sphere. For example, suitable methods are described in "Integrating Sphere Functionality: The Scatter Transmission Measurement – Technical Note" - Jeffrey L. Taylor, PerkinElmer, Inc.

The average reflectance of the rear foils may be 50% or more, 60% or more, 70% or more, 80% or more, 90% or more, 95% or more, 98% or more, 99% or more, up to or including 100% across one or more wavelengths in a range of from 400 nm and 1200 nm, preferably across all wavelengths in said range. Preferably, the average reflectance of the rear foils is in a range of from 70% to 100%, more preferably 80% to 100%, more preferably 90% to 100%, most preferably substantially 100% at said wavelengths. The higher the reflectance of the rear foils, the greater benefit may be derived in terms of improved efficiency of the solar cells, because a greater proportion of penetrating light may be reflected back toward the rear surfaces of solar cells in the solar cell assembly, providing a further opportunity for the light to be absorbed.

In comparison to this, the average reflectance of the front foils may be 10% or less, 5% or less, 2% or less, or 1 % or less across the same wavelengths. Preferably, the reflectance of the front foils is as low as possible, to avoid reflection of light that would otherwise be absorbed by the solar cell.

The rear foils may also have a higher reflectivity than the front foils. Reflectivity is the limit value of reflectance as the sample becomes thick; it is the intrinsic reflectance of the surface, hence irrespective of other parameters such as the reflectance of the rear surface. The values and

ratios as set out above in relation to reflectance may also apply to the values and ratios of reflectivities of the front and rear foils.

The materials from which the front and rear foils are respectively formed is not particularly limited, although the materials are preferably selected to be able to form a strong adhesion with both the surface of a solar cell, and with an encapsulant layer of a solar module (e.g. with an EVA layer). The front and/or rear foils may be electrically insulating. The front and/or the rear foils may comprise a polymeric material. They may comprise a polymeric material having one or more of: a high ductility, high optical transparency (for the front foil), good thermal stability, and/or high resistance to shrinkage. Exemplary polymer materials suitable for use in front and/or rear foils may include acetates (e.g. EVA), silicones, elastomers (e.g. POE), epoxy resin, fluoro-resin, polyamide resin, polysulfone, rayon, polyolefin, plastilene, rayonext, polyethylene terephthalate (PET), polyvinyl fluoride film and modified ethylene tetrafluoroethylene, etc. Most preferably, the front and/or rear foils may comprise TPO or POE.

The front and/or the rear foils may comprise a single layer of material. Alternatively, they may comprise two or more sub-layers, wherein two or more of these layers may include different materials and/or material characteristics. In some arrangements one of the front and the rear foil may comprise a single layer of material, whilst the other of the foils comprises two or more sub-layers. For example, the front foil may comprise a single layer of material, and the rear foil may comprise two or more sub-layers.

The thickness of the front and/or rear foils may be in a range of from 50µm to 150µm. In some embodiments, the thickness of the front and rear foils may be substantially identical. In other embodiments, the thickness of the front and rear foils may be different.

The manner in which the reflectance of the rear foil(s) is caused to be higher than the reflectance of the front foils is not particularly limited. Various exemplary arrangements are discussed below.

In some arrangements, the colour of the rear foil(s) may be selected to be a high-reflectance colour. For example the foil may be selected to have a white or substantially white colour. The colour of the foil may be an inherent material property of one or more materials forming part of the foil. Alternatively, the colour of the foil may be modified by application or addition of one or more pigments which increase the reflectance of the foil. For example the foil may comprise white or substantially white pigments. Suitable pigments include TiO<sub>2</sub> or any other pigment which can improve the reflectance of the foil. The pigment(s) may be particulate.

Such pigments may be provided on one or more surfaces of the foil (for example, they may be printed only one or more surface of the foil) or may be incorporated within the material of the foil. Where the foil is a polymeric material, the polymeric material may provide a host matrix for the pigment particles.

Where the pigments are incorporated into the material of the foil, they may be provided in an amount which provides the reflectance values specified above. That is, the amount of pigment in the foil may be selected such that the average reflectance of the rear foils is 50% or more, 60% or more, 70% or more, 80% or more, 90% or more, 95% or more, 98% or more, 99% or  
5 more, up to or including 100% across one or more wavelengths in a range of from 400 nm and 1200 nm, preferably across all wavelengths in said range.

In some arrangements, the rear foil(s) may comprise a reflective sub-layer. For example, the foil may comprise a metallic layer, e.g. an aluminium sub-layer or a copper sub-layer. A metallic sub-layer may itself be described as a 'foil', with the term 'foil' in this instance being used to  
10 define a thin layer of metal. The thickness of the metallic sub-layer may be in a range of from 15µm to 30µm.

If the foil comprises a metallic sub-layer, said layer is preferably not directly adjacent to the solar cell, to the conductive elements forming part of the foil-wire electrode assembly, or to other electrically conductive components of the solar cell assembly. For example, it may be provided  
15 as an outer layer of the rear foil, with another layer interposed between. This can help to prevent undesirable electrical connections from forming between the metallic sub-layer and other electrically conductive components of the solar cell assembly. Preferably, an insulating layer is disposed between the metallic sub-layer and electrically conductive components of the solar cell assembly, such as the solar cell surface, and conductive elements for electrically  
20 connecting solar cells in the assembly. This insulating layer may be a sub-layer of the rear foil.

In one convenient arrangement, the rear foil may comprise a polymeric sub-layer and a metallic sub-layer, wherein the polymeric sub-layer is laminated on the solar cell (with the conductive elements laminated between the polymeric sub-layer and the solar cell), and the metallic sub-layer is then directly laminated on the polymeric sub-layer, such that the polymeric sub-layer is  
25 interposed between the conductive elements/solar cell and the metallic sub-layer of the foil. The polymeric sub-layer may have a composition which is substantially similar to, or identical to, the composition of the front foil.

It is contemplated that in some arrangements, the rear foil portions may combine these two approaches, i.e. the rear foil portions may include both reflective pigments, and a reflective sub-  
30 layer. This may allow an even higher proportion of penetrating light to be reflect back to be absorbed by a rear face of the solar cells. Alternatively the approaches may be used in isolation (i.e. the foils may comprise pigments but no reflective sub-layer, or they may comprise a reflecting sub-layer but no reflective pigments).

Further optional and preferred features of the solar cell assembly will now be discussed in  
35 greater detail.

The plurality of cells may include at least first and second solar cells. The first and second solar cells may be electrically connected such that a front surface of the first solar cell is electrically

connected to a rear surface of the second solar cell by the plurality of conductive elements forming part of the foil-wire electrode assembly. The plurality of conductive elements may be conceptually divided to identify at least first and second portions of the conductive elements: a first portion which is arranged to electrically contact (i.e. to form an ohmic contact with) a front surface of the first solar cell – this first portion can be referred to as a front connector, and a second portion which is arranged to electrically contact (i.e. to form an ohmic contact with) a rear surface of the second solar cell – this second portion can be referred to as a rear connector. The electrical contact may be formed via one or more finger electrodes provided on the front and/or rear surfaces of the solar cells.

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- 10 In some arrangements, it is possible to conceptually divide the conductive elements into at least three portions, with the third portion being a portion which is arranged between the first and second portions of the plurality of conductive elements. The third portion may be configured to be arranged between the first and second solar cells when the foil-wire electrode assembly is connected therebetween. As will be discussed in further detail below, the first and second
- 15 portions are typically provided to be at least partially disposed in or on a respective foil portion of the foil-wire electrode assembly. In contrast to this, the part of the conductive elements defining the third portion which is arranged between the first and second solar cells when the foil-wire electrode assembly is connected therebetween may not be arranged to be in or on a foil. Rather, it may be arranged to extend between a front foil and a rear foil in the foil-wire
- 20 electrode assembly. Such an arrangement may be particularly suitable where a gap is maintained between adjacent solar cells of a solar cell string in the solar cell assembly, in that, the third portion may be positioned in the gap. However, in alternative embodiments, adjacent solar cells of a solar cell string may overlap such that no gap is maintained between these overlapping solar cells (also known as a shingled or gapless configuration). In this gapless
- 25 configuration, no third portion of the conductive elements may exist and, instead, the first portion may connect directly to the second portion at or near to the region of overlap.

Whilst the plurality of cells should include at least a first and second solar cell, as noted above, the maximum number of cells in the plurality of cells is not particularly limited. In some embodiments, the plurality of cells may include 3 or more cells, 4 or more cells, 10 or more

30 cells, 20 or more cells, 40 or more cells, or 60 or more cells, or 80 or more cells. The front surface of most or each solar cell in the plurality of solar cells may be electrically connected to the rear surface of at least one other solar cell in the plurality of solar cells by the plurality of conductive elements forming part of the foil-wire electrode assembly. The cells connected in this manner may form a solar cell string constituting part of the solar cell assembly. The solar

35 cell assembly may include multiple solar cell strings which are electrically connected together. For example, one or more strings may be connected in series and/or in parallel with one or more other strings.

The conductive elements may be configured to form an ohmic contact with an electrically conductive surface (e.g. an electrically conductive portion of a surface) of the solar cells. Each of the solar cells may comprise a layered structure which includes a photovoltaic element, as would be understood by the skilled person.

- 5    The conductive elements may be formed of an electrically conductive material, such as a metallic or metallic alloy material, which may comprise at least one of Sn, Ag, Al, Au and Cu, and/or mixtures thereof.

The conductive elements may comprise or consist of wires. At least one, or each, of the conductive elements may comprise a substantially constant cross-section along its length.

- 10   The number of conductive elements in the foil-wire electrode assembly is not particularly limited. In some arrangements, the number of conductive elements connecting adjacent solar cells in the foil-wire electrode assembly may be between 1 and 40, more preferably between 4 and 30, e.g. about 20.

- The conductive elements may comprise a coating which comprises an electrically conductive material which has a lower melting point compared to the underlying conductive element, such that the coating melts during lamination of the electrode assembly onto the solar cell. The coating may comprise a metal alloy formed of at least two or more components. The coating alloy may be at least one of a lead based, tin based and bismuth-based alloy. The coating may comprise a 2-phase, 3-phase, or more complex metal alloy. The coating may be formed of a metal alloy comprising at least one of Sn, Ag, Bi, Cd, Ga, In, Pb, Sn, Ti, etc. The coating may also comprise an electrically conductive material which is formed of metallic or alloy particles embedded within an organic matrix. Where such coating is provided, it may be configured to cover substantially the entire outer surface(s) of the conductive elements.
- 15   The conductive elements may comprise a coating which comprises an electrically conductive material which has a lower melting point compared to the underlying conductive element, such that the coating melts during lamination of the electrode assembly onto the solar cell. The coating may comprise a metal alloy formed of at least two or more components. The coating alloy may be at least one of a lead based, tin based and bismuth-based alloy. The coating may comprise a 2-phase, 3-phase, or more complex metal alloy. The coating may be formed of a metal alloy comprising at least one of Sn, Ag, Bi, Cd, Ga, In, Pb, Sn, Ti, etc. The coating may also comprise an electrically conductive material which is formed of metallic or alloy particles embedded within an organic matrix. Where such coating is provided, it may be configured to cover substantially the entire outer surface(s) of the conductive elements.
- 20   The conductive elements may comprise a coating which comprises an electrically conductive material which has a lower melting point compared to the underlying conductive element, such that the coating melts during lamination of the electrode assembly onto the solar cell. The coating may comprise a metal alloy formed of at least two or more components. The coating alloy may be at least one of a lead based, tin based and bismuth-based alloy. The coating may comprise a 2-phase, 3-phase, or more complex metal alloy. The coating may be formed of a metal alloy comprising at least one of Sn, Ag, Bi, Cd, Ga, In, Pb, Sn, Ti, etc. The coating may also comprise an electrically conductive material which is formed of metallic or alloy particles embedded within an organic matrix. Where such coating is provided, it may be configured to cover substantially the entire outer surface(s) of the conductive elements.

- A first portion of the foil-wire electrode assembly which contacts the front surface of a solar cell may define a front connecting portion, or front connector, of the foil-wire electrode assembly. A second portion of the foil-wire electrode assembly which contacts the rear surface of a solar cell may define a back-connecting portion, or back connector of the foil-wire electrode assembly. As mentioned above, a first portion of the plurality of conductive elements may define the front connector of the electrode assembly. A second portion of the plurality of conductive elements may define the back connector of the electrode assembly. Accordingly, the plurality of conductive elements may extend from the front connector to the back connector of the foil-wire electrode assembly.
- 25   A first portion of the foil-wire electrode assembly which contacts the front surface of a solar cell may define a front connecting portion, or front connector, of the foil-wire electrode assembly. A second portion of the foil-wire electrode assembly which contacts the rear surface of a solar cell may define a back-connecting portion, or back connector of the foil-wire electrode assembly. As mentioned above, a first portion of the plurality of conductive elements may define the front connector of the electrode assembly. A second portion of the plurality of conductive elements may define the back connector of the electrode assembly. Accordingly, the plurality of conductive elements may extend from the front connector to the back connector of the foil-wire electrode assembly.
- 30   A first portion of the foil-wire electrode assembly which contacts the front surface of a solar cell may define a front connecting portion, or front connector, of the foil-wire electrode assembly. A second portion of the foil-wire electrode assembly which contacts the rear surface of a solar cell may define a back-connecting portion, or back connector of the foil-wire electrode assembly. As mentioned above, a first portion of the plurality of conductive elements may define the front connector of the electrode assembly. A second portion of the plurality of conductive elements may define the back connector of the electrode assembly. Accordingly, the plurality of conductive elements may extend from the front connector to the back connector of the foil-wire electrode assembly.

- The conductive elements may be configured to bend along their axial length. This can allow the electrode assembly to be coupled between the respective front and rear surfaces of at least two solar cells in the plurality of solar cells (i.e. to allow the conductive element(s) to provide an electrical connection between the front and back connectors).
- 35   The conductive elements may be configured to bend along their axial length. This can allow the electrode assembly to be coupled between the respective front and rear surfaces of at least two solar cells in the plurality of solar cells (i.e. to allow the conductive element(s) to provide an electrical connection between the front and back connectors).

Each of the conductive elements may comprise a width, an axial length, and a depth. Each of the conductive elements may be configured such that its axial length is substantially greater than its width and/or depth. The width and axial length of the conductive elements may be measured in perpendicular directions aligned with a plane of the surface of the solar cell upon  
5 which the conductive elements are arranged (e.g. the front or rear surface of the solar cell). The depth may be measured in a direction which is perpendicular to the same plane of the solar cell.

In some embodiments, some or all of the conductive elements may be configured such that its width is between 0.2 mm and 0.4 mm, at its widest point, e.g. about 0.3 mm or 300  $\mu\text{m}$ . The length of some or all of the conductive elements may depend on the length of the solar cells in  
10 the solar cell assembly. In an exemplary arrangement, the conductive elements may be at least twice the length of a solar cell in the assembly, optionally  $\pm 10$  mm. The depth (i.e., the thickness) of some or all of the conductive elements may be between 0.2 mm and 0.4 mm, e.g. about 0.3 mm or 300  $\mu\text{m}$ .

As described above, the plurality of conductive elements may be arranged at least partially in  
15 and/or on the foil portions of the foil-wire electrode assembly. The foil portions may be configured to provide adhesion between the solar cells and the conductive elements so that the conductive elements are correctly spaced on the solar cells. In this way, the foil portions enable the conductive elements to be correctly aligned with the solar cells during manufacture of the solar cell assembly. The foil portions may provide a mechanical connection between the  
20 conductive elements and the solar cells. The conductive elements may be laminated on the front surface of solar cells in the plurality of solar cells between said surface and a front foil portion. They may be laminated on the rear surface of the second solar cell between said surface and a rear foil portion. In some embodiments, the conductive elements may be at least partially embedded in the front and/or rear foil portion(s).

25 The surface of the foil portions facing the conductive elements (which may also be referred to as a "solar cell-facing surface" of the foil portions) may be adhesive. In some arrangements, the material of the foil may comprise or consist of an adhesive material or have an adhesive property. For example, the foil may be a single layer foil that has an adhesive property. In other arrangements, a separate adhesive layer may be provided on the foil (e.g. the foil may  
30 comprise an adhesive sub-layer). Where an adhesive layer is provided, the adhesive may be substantially transparent. During fabrication of the solar cell assembly, heat and/or pressure may be applied to the foil portions to enable adherence of the foil portions to the conductive elements due to an application of force (e.g. by allowing softening of an adhesive layer, or of the adhesive foil material). In this way, the conductive elements may be at least partially embedded  
35 in the adhesive, and/or at least partially embedded in the foil. In embodiments, the conductive elements may be partially embedded in the adhesive but not actually contact the remaining portion of the foil. The front and/or rear foil portion(s) may be configured to provide structural

support for the conductive elements when the plurality of conductive elements are being handled, prior to being arranged onto the solar cell(s).

Each of the first and second solar cells may comprise a length, a width, and a depth. The length of the solar cell may be less than its width, and the depth may be less than both the width and the length. The longitudinal and transverse directions across the front and rear surfaces of the solar cell may be parallel with the length and width directions of the solar cell, respectively. Hence, the plurality of conductive elements may be configured to extend across the length of the solar cell, and to be spaced along its width.

Each of the conductive elements may be configured to extend lengthwise relative to the surface of the solar cell upon which it is overlaid, in a longitudinal direction. The conductive elements may be spaced apart in a transverse direction relative to the solar cell surface to define longitudinal-extending spaces between the conductive elements. The conductive elements may be parallel or substantially parallel to one another. The conductive elements may be equally or substantially equally spaced in the transverse direction. Accordingly, the plurality of conductive elements may form an array of parallel, transversely spaced (e.g. equally spaced) conductive elements.

Each of the solar cells' conductive surface(s) may comprise a plurality of finger electrodes which extend across the respective solar cell surfaces. The finger electrodes may be formed using a printed material, which enables them to be conveniently deposited onto the surfaces of the solar cells.

Each finger electrode of the pluralities of front and/or rear finger electrodes may be configured with an axial length which is substantially greater than its width. Both the width and axial length of the finger electrode may be measured in perpendicular directions in the plane of the respective surface of the solar cell. The finger electrodes may extend in a transverse direction which is parallel with the width direction of the solar cell.

The finger electrodes within each of the pluralities of front and/or rear finger electrodes may be spaced apart across the respective surface to define transversely extending spaces between the finger electrodes. The finger electrodes may be spaced apart in a longitudinal direction which is substantially parallel with the length direction of the solar cell. The finger electrodes in each plurality may be substantially parallel to one another.

The axial length of at least one finger electrode of the plurality of rear finger electrodes may be substantially misaligned (e.g. substantially non-parallel or substantially perpendicular) with the axial length of at least one of the conductive elements of the electrode assembly, which is overlaid upon it. Accordingly, the conductive elements of the electrode assembly may be configured to extend across the surface of the solar cell to form an ohmic contact with each of the plurality of finger electrodes.

The axial length of the finger electrode may be arranged substantially perpendicular with respect to the axial lengths of the overlaid conductive element. In this way, the conductive elements can be conveniently arranged to optimise the charge collection from the surface of the solar cell. Where a finger electrode is axially misaligned with an overlaid conductive element, 5 then the axial length of an associated finger electrode may be axially misaligned with each of the conductive elements by the same angle of misalignment, and vice versa.

The solar cell of the solar cell assembly may comprise a plurality of layers, or elements, including a photovoltaic element, wherein at least one of the plurality of layers is formed of a semiconductor material. The photovoltaic element (or layer) may be formed of a crystalline 10 silicon wafer.

It will be appreciated that the solar cell may comprise any suitable type of solar cell structure. For example, the solar cell may define a heterojunction type solar cell. Alternatively, the solar cell may define a tandem junction solar cell.

The surface(s) of the solar cell may be textured to form a textured surface corresponding to an uneven surface or having uneven characteristics. In this instance, an amount of light incident on 15 the solar cell increases because of the textured surface of the solar cell, and thus the efficiency of the solar cell is improved.

The solar cell may further comprise an anti-reflection layer, or coating, arranged at the front and/or rear surfaces of the solar cell. The, or each, anti-reflection layer may have a single- 20 layered structure or a multi-layered structure. The anti-reflection layer may be formed of silicon nitride (SiNx) and/or silicon oxide (SiOx). Alternatively, the anti-reflection layer may be formed of a transparent conductive oxide (TCO), such as indium tin oxide (ITO), which has been textured to provide an anti-reflective surface. The anti-reflection layer advantageously reduces the reflectance of light incident on the solar cell and increases selectivity of a predetermined 25 wavelength band, thereby increasing the efficiency of the solar cell.

The solar cell may comprise a transparent conductive oxide coating arranged at the front and/or rear surfaces of the solar cell. The transparent conductive oxide coating may be configured to increase lateral carrier transport to finger electrodes arranged on the respective surfaces of the solar cell.

30 One or more solar cell assemblies according to the present invention may be arranged in a housing to define a solar module.

Accordingly, in a third aspect, the present invention provides a solar module comprising a housing and one or more solar cell assemblies according to the present invention.

The solar module may comprise a frame in which to house the one or plural solar cell 35 assemblies. The frame may comprise a front plate and a back plate (also referred to as a 'backsheet') which are arranged, respectively, on the front and back sides of the plurality of

solar cell assemblies. At least one or each of the front and back plates may be formed of a substantially transparent material such as glass (e.g. a glass sheet).

5 In some preferred arrangements, the back plate or backsheet of the solar module may be dark in colour. For example, the backsheet may be substantially black, blue, green, brown or grey in colour. In this way, the aesthetic qualities of the module may be improved by provision of a low visual contrast between solar cells in the module and the dark backsheet. In some alternative arrangements, the back plate or backsheet of the solar module may be light in colour. For example, it may be white or substantially white in colour.

10 The solar module may comprise an encapsulant which may be configured to provide adhesion between the front and back plates and the plurality of solar cell assemblies. In this way, the encapsulant may be arranged between the glass sheet of the solar module, and an insulating optically transparent film of one of the pluralities of solar cell assemblies. Also, the encapsulant may be arranged between the back sheet of the solar module, and an insulating optically transparent film of one of the pluralities of solar cell assemblies. The encapsulant may be configured to prevent the ingress of moisture into the solar module. Accordingly, the  
15 encapsulant may be formed of ethylene vinyl acetate (EVA), or any other suitably moisture resistant material.

In a fourth aspect, the present invention provides a method of manufacturing a solar cell assembly according to the first aspect, the method comprising steps of:

20 providing first and second solar cells;  
providing a foil-wire electrode assembly comprising a plurality of conductive elements and a plurality of foil portions including at least one first foil portion and at least one second foil portion, wherein the second foil portion has a higher reflectance than the first foil portion;  
laminating the foil-wire electrode assembly on the first and second solar cells such that  
25 the at least one first foil portion is laminated on a front surface of the first solar cell, and the at least one second foil portion is laminated on a rear surface of the second solar cell.

The method may include steps of applying heat and/or pressure to laminate the foil-wire electrode assembly on the first and second solar cells.

30 The invention includes the combination of the aspects and preferred features described except where such a combination is clearly impermissible or expressly avoided. The skilled person will appreciate that except where mutually exclusive, a feature or parameter described in relation to any one of the above aspects may be applied to any other aspect and/or combined with any other feature or parameter described herein.

### 35 ***Summary of the Figures***

Embodiments and experiments illustrating the principles of the invention will now be discussed with reference to the accompanying figures in which:

Figure 1 is a close-up sectional side view of part of a solar module including a solar cell assembly according to a first embodiment of the present invention.

Figure 2 is a schematic plan view of part of the foil-wire electrode assembly used in the solar cell assembly depicted in Fig. 1.

- 5    Figures 3A and 3B are respectively plan (top) and transverse sectional schematic views of a first solar cell having a foil-wire electrode assembly laminated thereon, which form part of the solar cell assembly of the embodiment as shown in Fig. 1.

- Figure 4 is a transverse sectional schematic view of a solar cell having a foil-wire electrode assembly laminated thereon which forms part of a solar cell assembly of a second embodiment  
10    according to the present invention.

### ***Detailed Description of the Invention***

- Aspects and embodiments of the present invention will now be discussed with reference to the accompanying figures. Further aspects and embodiments will be apparent to those skilled in the  
15    art. All documents mentioned in this text are incorporated herein by reference.

- In the drawings, the thickness of layers, films, elements etc., are exaggerated for clarity. Furthermore, it will be understood that when an element such as a layer, film, region, or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being  
20    "directly on" another element, there are no intervening elements present.

- Fig. 1 shows a solar cell assembly 10 according to the present invention, which is arranged within a support assembly of a solar module 100 (e.g. a solar panel). The solar cell assembly 10 includes a first solar cell 20, a second solar cell 30 and a foil-wire electrode assembly 12 which is arranged to electrically couple a front surface 22 of the first solar cell 20 to a back surface 34  
25    of the second solar cell 30.

- Part of the foil-wire electrode assembly 12 used in the solar cell assembly 10 of Fig. 1 is also shown as a schematic plan (top) view in Fig. 2. The foil-wire electrode assembly comprises a plurality of conductive elements 18 and a plurality of foil portions 40 including front foil portions 40a which are configured to be laminated on respective front surfaces of solar cells, and rear  
30    foil portions 40b which are configured to be laminated on respective rear surfaces of solar cells. The front foil portion 40a is adjacent to the rear foil portion 40b along an axial length of the conductive elements of the foil-wire electrode assembly. The front foil portions 40a are substantially transparent. The rear foil portions 40b have a higher reflectance than the front foil portions. Provision of these higher-reflectance rear foils can provide for improved efficiency or  
35    power generation of a solar cell assembly incorporating the foil-wire electrode assembly, because light incident on a front face of the solar cell which penetrates through the cell may be

reflected by the higher-reflectance rear foil, thereby allowing capture of the reflected light by a rear face of the solar cells

In this first embodiment, the front and rear foil portions 40a, 40b each comprise a polymer material having a high ductility, good insulating characteristics, thermal stability, and resistance to shrinkage. As noted above the front foil is also optically transparent. The rear foil, in this  
5 embodiment, has a generally similar composition to the front foil material other than it also comprises a reflective pigment incorporated into the foil material – conveniently  $\text{TiO}_2$ , present in an amount of up to 10 wt% based on the total weight of the foil. An alternative embodiment is shown in Fig. 4, which is discussed in further detail below.

10 In this embodiment, which represents a traditional solar cell assembly arrangement where gaps are provided between solar cells in the arrangement, the plurality of conductive elements 18 can be conceptually divided to identify first, second and third portions of the conductive elements.

The first portion 18a of the conductive elements is arranged to be in electrical contact (i.e. to form an ohmic contact with) a front surface of the first solar cell – this first portion can be  
15 referred to as a front connector. This first portion is also attached to a respective front foil portion – either via an adhesive, by being partially embedded in the front foil, or both. The first portion of the conductive elements is laminated between the front foil portion and the front surface of the solar cell.

The second portion 18b of the conductive elements is arranged to be in electrical contact (i.e. to form an ohmic contact with) a rear surface of the second solar cell – this second portion can be  
20 referred to as a rear connector. This second portion is also attached to a respective rear foil portion – either via an adhesive, by being partially embedded in the rear foil, or both. The second portion of the conductive elements is laminated between the rear foil portion and the rear surface of the solar cell.

25 The third portion 18c is configured to be arranged between the first and second solar cells when the foil-wire electrode assembly is connected therebetween. In other words, this portion extends in a space between adjacent solar cells in the assembly. This third portion 18c bends between the respective upper and lower surfaces 22, 34 of the adjacently positioned solar cells 20, 30 of the solar cell assembly 10 when the foil-electrode arrangement is laminated on the  
30 solar cells in the context of a solar cell assembly. This portion of the conductive elements is not located in or embedded on either of the front or rear foils. It will be understood that for alternative arrangements, e.g. for shingled or gapless arrangements of solar cells, this third portion may not be present. Instead, the first portion may connect directly to the second portion at or near to the region of overlap. Such an arrangement is not shown in the present figures.

35 In Fig. 2, first portions of the conductive elements 18a are represented by dashed lines to illustrate that these portions underlie the front foil portion 40a in the plan view shown here. Second portions 18b and the intermediate portions 18c are represented by solid lines to

illustrate that these portions overlie the rear foil portion 40b in the plan view shown here. It will be understood that adjacent front and rear foil portions are therefore provided on opposite sides of the plurality of conductive elements in the foil-wire electrode array, in an 'over and under' arrangement. In other words, adjacent foils in the foil-wire array are arranged to be oppositely disposed about the conductive elements.

To apply the foil-wire electrode assembly to the solar cells (i.e. to laminate the foil-wire assembly on the solar cells), the conductive elements may be arranged with respect to the foil portions as shown in Fig. 2, and then the front and back foil portions 40a, 40b can be applied onto the respective surfaces of the solar cells. This step can include application of heat and/or pressure. This may cause the conductive elements 18 to become at least partially embedded within the front/rear foils 40a, 40b of the foil electrode assembly 40, as shown in Fig. 3B. This embedding can occur as on application of heat/pressure, the front/rear foil portions may conform around the conductive elements. They may also conform to the respective surfaces of the solar cells, and to any components disposed on front and rear surfaces of the solar cells (e.g. around finger electrodes printed on front and rear surfaces of the solar cells). Indeed, with reference to Fig. 3A and 3B, the front foil portion 40a is arranged to contact the front surface 22 of the solar cell in the areas in-between the conductive elements 18 and the front finger electrodes 26a. The rear foil portion 40b is arranged to contact the rear surface 24 of the solar cell in the areas in-between the conductive elements 18 and the rear finger electrodes 26b.

In this way, the front and rear foil portions provide adhesion between the solar cells and the conductive elements 18 so that the conductive elements are correctly arranged on the solar cells (i.e. aligned with the finger electrodes).

The solar cell assembly 10 arranged within the support assembly 102 includes further cells that are not shown in fig. 1. For example, a front surface 32 of the second solar cell 30 is electrically coupled to the back surface of a third solar cell (not shown) by a further portion of the foil-wire electrode assembly. A back surface 24 of the first solar cell 20 is also coupled to the front surface of a fourth solar cell (not shown) by a further portion of the foil-wire electrode assembly. The plurality of solar cells in the module are thereby coupled by the foil-wire electrode assembly

A front plate 104 of the support assembly 102 comprises a transparent (e.g. glass) sheet which is configured to allow light to pass through into a central chamber 106 in which the solar cell assembly 10 is mounted. The arrows at the top of Fig. 1 show the direction of the solar radiation which is incident upon the solar cell assembly 10.

A back plate 108 of the support assembly 102 is arranged to enclose the solar cell assembly 10 within the central chamber 106. The back plate 108 may comprise a reflective sheet which is configured to reflect any light which is incident upon its upper surface, back towards the solar cell assembly 10, but may also not comprise a reflective sheet, and may be dark in colour. For example, this back sheet may be black or substantially black in colour, thereby allowing for

reduced visual contrast with solar cells in the module and an improved aesthetic appearance of the module.

The central chamber 106 is filled with an encapsulating material (the shaded area shown in Fig. 1) which prevents ingress of external liquid or gaseous entrants. The encapsulating material is  
5 any suitable encapsulating material used in the art, for example EVA.

Figs. 3A and 3B respectively illustrate plan (top) and transverse sectional views of a first solar cell 20 of the solar cell assembly 10, said solar cell having a foil-wire electrode assembly laminated thereon. Fig. 3B is a sectional view taken along dashed line A-A as shown in Fig. 3A. The remaining solar cells in the solar module are generally identical to this first solar cell and so  
10 do not need to be specifically described here. The solar cell 20 has a length which is the vertical dimension of Fig. 3A, and a width which is the horizontal dimension of Fig. 3A.

As shown in Fig. 1, when arranged in the solar module, the first and second solar cells 20, 30 are arranged in a common transverse plane such that their width-wise and lengthwise dimensions lie in parallel with each other. Each of the front surfaces 22, 32 of the respective  
15 solar cells define a surface on which light is incident when the solar cell assembly 10 is in use. The back surfaces 24, 34 each define a surface which is opposite to the respective front surface 22, 32.

Each solar cell 20, 30 includes a layered structure (not shown) arranged between its respective front and back surfaces. The layered structure is a multi-layer semiconductor assembly which  
20 includes a photovoltaic element (or layer) which is configured to generate electrical charge carriers from the absorption of incident radiation.

Each solar cell comprises front and back finger electrodes provided on front and back surfaces of the respective solar cell, said finger electrodes being configured to conduct away the electrical charge carriers generated by the respective solar cell 20, 30. That is, the first solar  
25 cell 20 includes a first plurality of finger electrodes arranged on its front surface 22 (i.e. front finger electrodes), and a second plurality of finger electrodes arranged on its back surface 24 (i.e. back finger electrodes). Similarly, the second solar cell 30 includes a first plurality of finger electrodes arranged on its front surface 32, and a second plurality of finger electrodes arranged on its back surface 34. Not all of these finger electrodes are shown in the figures of the present  
30 application. In Fig. 3A, the front finger electrodes of the first solar cell are represented by horizontally-extending lines 26a. In Fig. 3B, the sectional view is taken through the top and bottom finger electrodes 26a, 26b of the first solar cell, which therefore can be seen to extend along the front and rear surfaces of the solar cell. The fingers electrodes of the second solar cell are not shown. The finger electrodes are formed of an electrically conductive material e.g.  
35 formed of a metallic alloy comprising Ag. The electrically conductive material is a printed material, which enables the finger electrodes to be conveniently deposited onto the respective surfaces of the solar cells. The printed material is formed using a printable precursor, such as a

conductive paste, which comprises a mixture of silver metal powder and glass frit suspended in a solvent. The conductive paste may be fired, or cured, to form the finger electrodes.

As shown in Fig. 3B, the conductive elements of the foil-wire electrode arrangement are arranged to be in electrical contact with the front and back surfaces of the solar cells via the finger electrodes 26a, b provided on the front and back surfaces of the cells. The conductive elements are configured to form an ohmic contact with these finger electrodes. The conductive elements 18 are conveniently provided as wires having an integral elongate form and are formed of an electrically conductive material. For example, the conductive elements 18 comprise a metallic alloy material, which includes at least one of Ag, Al, Au and Cu. Whilst not shown in these figures, the conductive elements 18 comprise a coating which is configured, when in use, to solder the respective conductive elements to a surface of the solar cells 20, 30 upon which they are overlaid. The coating is an electrically conductive material having a melting point which is lower than that of the conductive element 18. The coating comprises a metal alloy formed of at least two or more components, such as a lead based, tin based and bismuth-based alloy. Alternatively, the coating may comprise a 2-phase, 3-phase, or more complex metal alloy, as would be understood by the skilled person.

As the conductive elements 18 and their coating are both formed of an electrically conductive material, they are configured to allow electrical charge carriers to flow between the conductive elements 18 and the finger electrodes on the front and back surfaces of the first and second solar cells 20, 30. In this way, each of the conductive elements 18 defines a current collector of the electrode assembly 12. Furthermore, the conductive elements 18 are configured to collect charge carriers from the front finger electrodes of the first solar cell 20 and transport them to the back-finger electrodes of the second solar cell 30, or vice versa.

The pluralities of front and back finger electrodes are arranged to extend across the solar cells 20, 30 in the transverse direction (the horizontal direction in Fig. 3A) and are equally spaced apart in the longitudinal direction (the vertical direction in Fig. 3A).

The dimensions of each finger electrode are substantially the same as that of every other finger electrode. For example, the finger electrodes have a common length, width and depth such that each electrode is arranged to protrude from the surface of the solar cell by the same amount. Furthermore, each of the finger electrodes has a rectangular cross-section (which is measured perpendicular to the electrode's length).

The finger electrodes arranged on each of the front and back surfaces of the solar cells 20, 30 are aligned in parallel with each other, and with a corresponding finger electrode on the opposite side of the solar cell. For example, each one of the finger electrodes 26a arranged on the front surface 22 of the first solar cell 20 is longitudinally aligned with a corresponding finger electrode 26b from the plurality of back finger electrodes. As shown in Fig. 3A, each of the pluralities of front and back finger electrodes comprises twelve electrodes. However, it is to be

understood that in some other embodiments, the number of front and back finger electrodes may be different.

The number of conductive elements 18 of the electrode assembly 12 connecting an adjacent pair of solar cells is between four and twenty. In the embodiment described herein and shown schematically in the figures, the electrode assembly 12 has sixteen conductive elements 18 as shown in Figs. 3A and 3B. However, it will be appreciated that, in some other embodiments, a different number of conductive elements may be present.

The first and second portions 18a, 18b of the plurality of conductive elements 18 are parallel and extend lengthwise relative to the front and back surfaces 22, 34 of the solar cells, in a longitudinal direction (e.g. in the vertical direction in Fig. 3A). The conductive elements 18 are also equally spaced apart in a transverse direction relative to the front and back surfaces 22, 34 (e.g. the horizontal direction in Fig. 3A) to define longitudinal-extending spaces between the conductive elements 18. Accordingly, each one of the first and second portions 18a, 18b defines an array of parallel, transversely spaced conductive elements 18.

Each of the first portions 18a of the plurality of conductive elements 18 are axially aligned with the corresponding second portions 18b of the conductive elements 18 of the same electrode assembly 12.

According to the above described arrangement, it will be understood that the pluralities of front and back finger electrodes are arranged perpendicular to the first and second portions 18a, 18b of the plurality of conductive elements 18, as shown in Fig. 3A.

Fig. 4 is a transverse sectional schematic view of a solar cell having a foil-wire electrode assembly laminated thereon which forms part of a solar cell assembly of a second embodiment according to the present invention. The features of this embodiment are substantially identical to that of the first embodiment, other than for the configuration of the rear foil portion. In this embodiment, the rear foil portion does not comprise reflective pigments (as in the first embodiment). Instead, a reflective metallic sub-layer 40b'' (e.g. a thin layer of aluminium) is provided as part of the rear foil. This metallic sub-layer is arranged so that it is not directly adjacent to the solar cell, to the conductive elements forming part of the foil-wire electrode assembly, or to other electrically conductive components of the solar cell assembly: rather, it is provided as an outer layer of the rear foil. In this embodiment the rear foil also comprises a polymeric sub-layer 40b' in addition to the reflective metallic sub-layer 40b''. The polymeric sub-layer has an identical composition as the front foil 40a. The polymeric sub-layer 40b' is laminated on the solar cell (with the conductive elements 18 laminated between the polymeric sub-layer and the solar cell), and the metallic sub-layer 40b'' is then directly laminated on the polymeric sub-layer, such that the polymeric sub-layer is interposed between the conductive elements/solar cell and the metallic sub-layer of the foil. This can help to prevent undesirable electrical connections from forming between the metallic sub-layer and other electrically

conductive components of the solar cell assembly, whilst still allowing for good reflectance from the metallic sub-layer, thereby increasing efficiency of the solar cell.

The features disclosed in the foregoing description, or in the following claims, or in the accompanying drawings, expressed in their specific forms or in terms of a means for performing  
5 the disclosed function, or a method or process for obtaining the disclosed results, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled  
10 in the art when given this disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

For the avoidance of any doubt, any theoretical explanations provided herein are provided for  
15 the purposes of improving the understanding of a reader. The inventors do not wish to be bound by any of these theoretical explanations.

Any section headings used herein are for organizational purposes only and are not to be construed as limiting the subject matter described.

Throughout this specification, including the claims which follow, unless the context requires  
20 otherwise, the word "comprise" and "include", and variations such as "comprises", "comprising", and "including" will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

It must be noted that, as used in the specification and the appended claims, the singular forms  
25 "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Ranges may be expressed herein as from "about" one particular value, and/or to "about" another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by the use of the antecedent "about," it will be understood that the particular value forms another embodiment. The term "about" in relation to a numerical value is optional  
30 and means for example +/- 10%.

**Claims:**

1. A solar cell assembly comprising a plurality of solar cells interconnected by a foil-wire electrode assembly, the foil-wire electrode assembly comprising a plurality of conductive  
5 elements and a plurality of foil portions including front foil portions laminated on respective front surfaces of the plurality of solar cells, and rear foil portions laminated on respective rear surfaces of the plurality of solar cells, wherein the rear foil portions have a higher reflectance than the front foil portions.
2. The solar cell assembly according to claim 1 wherein the average reflectance of the rear  
10 foil portions is 50% or more across one or more wavelengths in a range of from 400 nm and 1200 nm.
3. The solar cell assembly according to claim 2 wherein the average reflectance of the rear foil portions is substantially 100% across one or more wavelengths in a range of from 400 nm and 1200 nm.
- 15 4. The solar cell assembly according to any one of the preceding claims wherein the average reflectance of the front foil portions is 10% or less across one or more wavelengths in a range of from 400 nm and 1200 nm.
5. The solar cell assembly according to any one of the preceding claims wherein the colour of the rear foil portions is selected to be a high-reflectance colour, optionally wherein the rear  
20 foil portions are white or substantially white in colour.
6. The solar cell assembly according to any one of the preceding claims wherein the rear foil portions comprise one or more pigments provided (i) on a surface of the foil and/or (ii) incorporated within the material of the rear foil portions.
7. The solar cell assembly according to claim 6 wherein the rear foil portions comprise one  
25 or more pigments incorporated within the material of the rear foil portions in an amount such that the average reflectance of the rear foils of 50% or more.
8. The solar cell assembly according to claim 6 or claim 7 wherein the one or more pigments include  $\text{TiO}_2$ .
9. The solar cell assembly according to any one of the preceding claims wherein the rear  
30 foil portions comprise a reflective sub-layer, optionally a metallic sub-layer.
10. The solar cell assembly according to claim 9 wherein the rear foil portions comprise a metallic sub-layer, and wherein an insulating layer is disposed between the metallic sub-layer and electrically conductive components of the solar cell assembly.
11. The solar cell assembly according to claim 10 wherein the rear foil portions comprise a  
35 polymeric sub-layer and a metallic sub-layer, wherein the polymeric sub-layer is directly

laminated on the solar cell to which each foil portion is respectively attached, and the metallic sub-layer is directly laminated on the polymeric sub-layer such that the polymeric sub-layer is interposed between the solar cell and the metallic sub-layer of the foil portion.

12. The solar cell assembly according to any one of the preceding claims wherein the front and/or the rear foil portions comprise a polymeric material, optionally wherein the foil portions comprise a material selected from an acetate (e.g. EVA), a silicone, an elastomer (e.g. POE), epoxy resin, fluororesin, polyamide resin, polysulfone, rayon, polyolefin, plastilene, rayonext, polyethylene terephthalate (PET), polyvinyl fluoride film and modified ethylene tetrafluoroethylene.

13. The solar cell assembly according to any one of the preceding claims wherein the thickness of the front and/or rear foils is in a range of from 50µm to 150µm.

14. The solar cell assembly according to any one of the preceding claims wherein the plurality of cells includes at least first and second solar cells wherein the first and second solar cells are electrically connected such that a front surface of the first solar cell is electrically connected to a rear surface of the second solar cell by the plurality of conductive elements, with a first portion of the plurality of conductive elements being arranged to be in electrical contact with the front surface of the first solar cell, a second portion of the plurality of conductive elements being arranged to be in electrical contact with a rear surface of the second solar cell, a third portion of the plurality of conductive elements being arranged to extend between the first and second portions of the plurality of conductive elements to thereby connect the front surface of the first solar cell with the rear surface of the second solar cell.

15. A solar module comprising a housing and one or more solar cell assemblies according to any one of claims 1 to 14.

16. The solar module according to claim 15 wherein the module comprises a frame housing the one or more solar cell assemblies, wherein the frame comprises a front plate and a back plate, wherein the front plate is formed of a substantially transparent material, and the back plate is dark in colour.

17. A foil-wire electrode assembly, the foil-wire electrode assembly comprising a plurality of conductive elements and further comprising a plurality of foil portions including at least one first foil portion and at least one second foil portion, wherein the second foil portion has a higher reflectance than the first foil portion.

18. A method of manufacturing a solar cell assembly according to any one of claim 1 to 14, the method comprising steps of:

providing first and second solar cells;

providing a foil-wire electrode assembly comprising a plurality of conductive elements and a plurality of foil portions including at least one first foil portion and at least one second foil portion, wherein the second foil portion has a higher reflectance than the first foil portion;

laminating the foil-wire electrode assembly on the first and second solar cells such that the at least one first foil portion is laminated on a front surface of the first solar cell, and the at least one second foil portion is laminated on a rear surface of the second solar cell.