

## AN ELECTRODE ASSEMBLY AND A METHOD OF MANUFACTURING AN ELECTRODE ASSEMBLY

### FIELD OF THE DISCLOSURE

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The present disclosure relates to an electrode assembly, solar cell string, and methods of forming an electrode assembly and solar cell string.

### BACKGROUND

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A typical solar module for providing electrical energy from sunlight comprises an array of solar cells, each comprising a photovoltaic element, or substrate. Solar cells in an array are typically electrically connected in series to form a row of connected solar cells, sometimes referred to as a solar cell string. To facilitate this electrical connection, and to extract charge carriers from the solar cells, electrically conductive elements (such as bus bars) are typically provided on surfaces of each solar cell (sometimes referred to as metallisation), which either connect directly or indirectly to adjacent cells in the solar cell string.

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The most common solar cell architectures necessitate that the electrically conductive elements are provided on both the front and back surfaces of a solar cell. As may be appreciated, placement of such conductive elements on the front surface, especially, can reduce the amount of light entering the solar cell (i.e. creating "shading"). Given the efficiency of a solar cell is highly dependent on the amount of light received by a photovoltaic element of the solar cell, this shading by the electrically conductive elements can reduce efficiency of a solar cell.

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Back contact solar cells, such as interdigitated back contact (IBC) solar cells, have been developed to address this problem. The architecture of an IBC solar cell is such that electrically conductive elements can be moved from the front surface of a solar cell to the rear surface so that all "metallisation" is provided on the back surface of the solar cell (i.e. avoiding any shading on the front surface). In general, IBC solar cells include both p-type regions and n-type regions provided at the back surface of the solar cell. Like more traditional architectures, to provide a flow of electricity along a solar cell string, each p-type region is electrically connected to an n-type region of an adjacent cell and, conversely, each n-type region is electrically connected to the p-type region of another adjacent cell.

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**SUMMARY**

In general, the present disclosure provides a method of connecting solar cells of the type having all metallisation on a back surface, using a film and a plurality of electrically conductive elements.

In a first aspect, there is provided a method of forming an electrode assembly for electrically connecting  
5 a row of solar cells, the method comprising:

providing a longitudinally extending film arrangement having first and second opposite sides;

arranging a plurality of longitudinally extending, transversely spaced, electrically conductive members on the first side of the film arrangement, the plurality of conductive members comprising a plurality of first conductive members arranged in an alternating manner  
10 transversely across the film arrangement with a plurality of second conductive members; and

forming a plurality of electrical disconnections in the conductive members to divide each conductive member into a plurality of electrically conductive elements, the electrical disconnections arranged in substantially transverse rows that are longitudinally spaced from one another so as to define a plurality of cell regions therebetween, each cell region for  
15 positioning on a respective solar cell of the row of solar cells,

wherein the rows of electrical disconnections alternate in the longitudinal direction between:

a first row type in which each electrical disconnection is formed in a respective first conductive member; and

a second row type in which each electrical disconnection is formed in a respective  
20 second conductive member.

As may be appreciated, positioning the cell region on the surface (e.g. the back surface) of a solar cell may allow the conductive members to connect the solar cell to adjacent solar cells. The above-described electrical disconnections (also referred to as just "disconnections" below) effectively divide  
25 each electrically conductive member into a plurality of colinear electrically conductive elements (i.e. each member being formed of a plurality of disconnected conductive elements). The positioning of the disconnections means that, when the cell region is positioned on a solar cell, some of the electrically conductive elements connect the solar cell to a first adjacent solar cell (only) and the remaining electrically conductive elements connect the solar cell to an opposite second adjacent solar cell (only).

In this way, the method of the first aspect may provide a way of forming a solar cell electrode (i.e. providing electrical connection to adjacent solar cells) in a simple, cost-effective manner. For example, configuring the conductive elements in this way removes the need to provide separate connections (such as copper ribbons) between overlapping solar cells, which thereby reduces the number and complexity of manufacturing steps required to fabricate the solar cell assembly.  
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One effect of providing all of the metallisation on the back surface of an IBC solar cell is that it effectively doubles the number of electrically conductive elements on the back surface. A consequence of this is that these conductive elements are typically spaced closer together. This can create a higher risk of

short circuiting (i.e. two electrically conductive elements touching to create a short-circuit) and a higher risk of an electrically conductive element being positioned on an incorrect region of the back surface during assembly. In either case, this can impact operation of a solar cell. The method of the first aspect minimises the possibility of misalignment of the electrically conductive member by provision of the film arrangement that maintains the desired spacing of the electrically conductive members.

For the avoidance of doubt, the reference to the first and second conductive members being arranged in an alternating manner means that, moving in a transverse direction across the conductive members, the electrically conductive elements follow a repeating pattern of first conductive member then second conductive member.

Likewise, the term "electrical disconnection" refers to a feature formed in the respective conductive member that prevents the passage of electricity along the conductive member (i.e. across the electrical disconnection). As is discussed further below, one example of such an electrical disconnection is a gap formed in the conductive member.

Optional features of the first aspect will now be set out. These are applicable singly or in any combination with any aspect of the disclosure.

The method may comprise forming e.g. three or more rows of disconnections (i.e. resulting in at least two cell regions). The method may comprise forming e.g. five or more rows of disconnections (i.e. resulting in at least four cell regions). The method may comprise forming eleven disconnections. The electrode assembly produced by such a method may, for example, be suitable for use in a solar cell string comprising ten solar cells (each provided on a respective cell region).

Each electrically conductive element may span two respective cell regions (i.e. including any gap between the two respective cell regions). Each conductive element may extend fully (longitudinally) across each of the two respective cell regions.

Each transverse row of disconnections may be arranged along a reference line that extends perpendicularly to the longitudinal conductive elements. In other embodiments, however, each transverse row may extend along a line that is angled to such a reference line (e.g. by an angle that is less than 15 degrees). Likewise, the disconnections in a transverse row may be staggered with respect to such a reference line (i.e. may not all be aligned exactly on such a reference line).

As set forth above, the rows of disconnections form cell regions therebetween, each for positioning on a respective solar cell (e.g. the back surface of a solar cell). As may be appreciated, one or more of the cell regions (e.g. all cell regions except those at opposite ends) may be disposed between respective first and second adjacent cell regions. Each of such one or more cell regions may comprise thereon:

a plurality of first electrically conductive elements, each extending from the cell region to the first adjacent cell region and not to the second adjacent cell region; and

a plurality of second electrically conductive elements spaced transversely across said cell region in an alternating manner with the first electrically conductive elements, and wherein each  
5 second electrically conductive element extends from the cell region to the second adjacent cell region and not to the first adjacent cell region.

In some embodiments, all of the cell regions (except for those at opposite ends of the longitudinal row of cell regions) may have conductive elements thereon arranged in the above-described manner.

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Each disconnection may be in the form of a longitudinally extending gap (i.e. between adjacent conductive elements of a conductive member). Each gap may be formed by cutting through a conductive member (i.e. to divide the conductive member into separate conductive elements). Each gap may be formed by cutting through the conductive element at two longitudinally spaced apart  
15 locations on the respective conductive member (the gap being formed between the two locations). Each gap may, for example, have a length (in the longitudinal direction) of from 1 mm to 12 mm, or e.g. from 1 mm to 9 mm. As may be appreciated, in some embodiments the gap may be filled (i.e. spanned) by an insulative element.

20 The method may comprise forming the disconnections of each row of disconnections (e.g. gaps) concurrently. For example, when each disconnection is a gap, each row of gaps may be formed in a single cutting action. The single cutting action may be performed, for example, using a cutting tool. The cutting tool may be configured to cut alternate (i.e. in the transverse direction) conductive members.

25 For example, the cutting tool may comprise a row of transversely spaced apart blades. The transverse spacing of the blades (e.g. taken between centres of the blades) may be greater than (e.g. about double) the transverse spacing of the conductive members (e.g. taken between centres of the conductive members).

30 The row of spaced apart blades may extend in a row direction (the row direction may be parallel to the transverse direction). Each blade of the row of spaced apart blades may have a cutting edge (i.e. an edge arranged to cut a conductive member). Each cutting edge may be oriented so as not to be perpendicular to the row direction. Each cutting edge may be oriented so as to be parallel to the row direction. Each cutting edge may be linear (i.e. straight).

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In some embodiments, the row of blades of the cutting tool may be a first row of blades and the cutting tool may comprise a second row of blades longitudinally spaced from the first row of blades. The second row of blades may be as described above with respect to the first row of blades. Each blade of the second row of blades may be aligned (in the transverse direction) with a respective blade in the first  
40 row of blades to define a pair of blades. Each pair of blades, when used to cut through a respective

conductive member, may thus form a gap in the conductive member. Each pair of blades may therefore be referred to as a gap forming portion.

5 The blades of the second row of blades may be as described above with respect to the blades of the first row of blades. For example, each blade of the second row of blades may comprise a cutting edge, which may be oriented so as to be non-perpendicular to (e.g. parallel to) the row direction of the second row of blades.

10 The cutting tool may comprise half the number of pairs of blades as the number of conductive members. The cutting tool may comprise between e.g. 18 and 22 pairs of blades (e.g. between 36 and 44 blades in total when the second row of blades is present).

The cutting tool may be as otherwise described in the seventh aspect.

15 The method may comprise performing a plurality of cutting actions using the cutting tool, each cutting action forming a respective transverse row of disconnections (e.g. gaps) in the conductive members as described above. The method may comprise moving the conductive members, relative to the cutting tool, in a longitudinal direction between successive cutting actions. As may be appreciated the longitudinal distance of such movement may define the longitudinal distance between adjacent rows of  
20 disconnections.

The method may comprise moving the cutting tool, relative to the conductive members, in a transverse direction between successive cutting actions. This transverse movement may be a distance that is the same as the transverse spacing between the conductive members. Thus, this transverse movement  
25 may provide the alternating arrangement of disconnections in successive rows as described above (i.e. alternating between disconnections in the first conductive members and disconnections in the second conductive members).

30 In another embodiment the method may comprise first and second cutting tools (i.e. each being as described above). The first and second cutting tools may be spaced longitudinally from one another (e.g. by a distance equivalent to the longitudinal distance between adjacent rows of connections). The first cutting tool may be offset in the transverse direction relative to the second cutting tool. That is, the teeth of the first cutting tool may be offset in the transverse direction relative to the teeth of the second cutting tool. This transverse offset may be a distance that is the same as the transverse spacing  
35 between the conductive members. In this way, when the first and second cutting tools are used to cut the conductive members, the conductive members cut by the first cutting tool are different to (i.e. are interspersed between) the conductive members cut by the second cutting tool. In other words, the first and second cutting tools are able to provide the alternating arrangement of disconnections in successive rows as described above (without needing to move the cutting tools transversely between  
40 cutting actions).

In such embodiments (in which first and second cutting tools are provided) the conductive members may be moved longitudinally, relative to the first and second cutting tools) between cutting actions by a distance that is equivalent to twice the distance between adjacent rows of disconnections.

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The second side of the film arrangement may be substantially free of electrically conductive elements. Thus, the method may not include a step of arranging electrically conductive members on the second side (i.e. the method may comprise arranging electrically conductive members on the first side of the film arrangement only). In some embodiments, the second side of the film may comprise one or more electrically conductive members or elements, but such conductive elements or members may not be arranged in the manner described above (i.e. may not be longitudinally extending and transversely spaced with rows of disconnections formed therein).

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The film arrangement may comprise a single film (i.e. a unitary film). The film may be substantially planar. In such embodiments, forming each disconnection may comprise cutting through the film (i.e. in addition to the respective conductive member). This may ensure complete removal of the cut material (i.e. to ensure the formation of a gap in the conductive member).

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The film arrangement (e.g. the one or more films of the film arrangement) may be formed of a polymeric material. The polymeric material may be formed from a polymer resin which comprises, for example, at least one of a polyolefin elastomer (POE), polyvinylbutyral (PVB) hydrocarbon ionomer, thermoplastic organo-silicon, silicon rubber, polyurethane, thermoplastic silicone elastomer (TPSE) and ethylene-vinyl acetate (EVA). Patent document PCT/EP2022/085158, which is incorporated herein by reference discloses, for example, a suitable material for formation of the film arrangement.

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In other embodiments, the film arrangement may comprise a longitudinally extending row of films. Each film may be planar. The films may be spaced from one another in the longitudinal direction. Each film may be substantially rectangular. In such embodiments, each row of disconnections may be formed at least partly between two adjacent films. Thus, each film may be between (or at least substantially between) two rows of disconnections. Each cell region (i.e. as described above) may be defined by a respective film (e.g. may be at least a portion of a surface of a film or may cover substantially the whole surface of respective film).

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The film arrangement (e.g. the film(s)) may be configured to be electrically insulating and/or optically transparent. The film arrangement may be configured to provide adhesion between a solar cell and the conductive elements (when the electrode assembly is positioned thereon) so that the conductive elements are correctly spaced on the solar cell after assembly. In this way, the film arrangement may facilitate correct alignment of the conductive elements with regions of a solar cell.

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The film arrangement (e.g. the film(s)) may be deformable when heated to allow the conductive members (and thus conductive elements) to be at least partially embedded in the first side of the film arrangement. The film arrangement may be configured such that at least a portion of each conductive element is exposed from the film arrangement to form an electrical contact with the back surfaces of the solar cells. The method may comprise heating the film arrangement (e.g. to deform the film arrangement so as to embed the conductive members). Alternatively, the first side of the film arrangement may be coated with an adhesive which adheres the conductive members (and conductive elements) to the film arrangement.

10 The film arrangement (e.g. each film) may comprise multiple layers, or may comprise a single layer.

The method may comprise arranging between 30 and 60 conductive members on the film arrangement, or e.g. 36 to 44 conductive members on the film arrangement.

15 The electrode assembly may be referred to as a foil-wire electrode assembly. Each conductive member (and thus each element) may be a wire or wire portion. Each conductive member (prior to the formation of disconnections) may comprise a single integrally formed element (e.g., a wire).

20 Arranging the conductive members (e.g. wires) may comprise tensioning the conductive members (e.g. via a wire pulling station).

25 The conductive members may be parallel or substantially parallel to one another. The conductive members may be equally or substantially equally spaced in the transverse direction. Accordingly, the plurality of conductive members may form an array of parallel, transversely spaced (e.g., equally spaced) conductive elements.

30 Each of the conductive members (and conductive elements) may comprise a width, an axial length, and a depth. Each of the conductive members (and 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 members (and conductive elements) may be measured in perpendicular directions aligned with a plane along which the film arrangement extends, or a plane of the surface of the solar cell upon which the conductive elements are ultimately arranged in use of the electrode assembly (e.g., the back surface of the solar cell). The depth (e.g., thickness) may be measured in a direction which is perpendicular to the same plane of the film arrangement or solar cell.

35 The conductive element(s) may be formed of an electrically conductive material, such as a metallic or metallic alloy material, which may include at least one of Ag, Al, Au, and Cu.

According to an exemplary arrangement, each of the plurality of conductive members (and thus elements) may comprise a coating which is configured, when in use, to solder the conductive elements to the respective surfaces of the solar cells upon which they are overlaid.

- 5 The coating (i.e., the solderable coating) may comprise an electrically conductive material having a melting point which is lower than that of a core of the conductive element. 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 Ag, Bi, Cd, 10 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.

The step of arranging the conductive elements on the film arrangement may comprise arranging the conductive elements so as to be at least partly embedded in the film arrangement.

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In a second aspect, there is disclosed a method of forming a solar cell string, the method comprising:

forming an electrode assembly according to the method of the first aspect; and

arranging a plurality of solar cells on the electrode assembly, each solar cell being arranged on a respective cell region of the electrode assembly so as to be electrically connected to the 20 electrode assembly at the cell region.

Optional features of the second aspect will now be set out. These are applicable singly or in any combination with any aspect of the disclosure.

- 25 The method may comprise detecting a position of each cell region in space (or e.g. each film of a film arrangement). The method may comprise detecting a transverse position of each cell region (or film). The method may comprise detecting a longitudinal position of each cell region (or film). The method may comprise, for example, detecting one or more edges (e.g. longitudinal and/or transverse edges) of each film. The method may, for example, comprise determining whether (and e.g. by how much) the position (e.g. a longitudinal and/or transverse position) of a cell region (or film) deviates from a desired 30 position. Such detection may be performed by a vision system configured to identify (e.g. via an object detection algorithm) a cell region. The vision system may be configured to identify a film (and e.g. determine the position of the film in space, such as relative to a conveyor).

- 35 The method may comprise, prior to arranging the plurality of solar cells on the electrode assembly, arranging the plurality of solar cells in a row (e.g. a longitudinally extending row). The method may comprise moving (e.g. conveying) the row of solar cells (e.g. in a longitudinal direction). The row of solar cells may, for example, be provided on a belt conveyor. The method may comprise controlling the speed of movement of the row of solar cells based on the detected position of a cell region.

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The method may comprise conveying the electrode assembly (e.g. longitudinally). The electrode assembly may, for example, be provided on a belt conveyor, such as a vacuum conveyor belt or a combination of two belts that clamp the electrode assembly. The method may comprise controlling the speed of movement of the electrode assembly based on the detected position of a cell region. The method may comprise controlling the speed of movement of the electrode assembly based on a determined deviation of the longitudinal position of the electrode assembly from a desired longitudinal position. The electrode assembly may be transversely spaced from the row of solar cells.

The method may comprise adjusting a transverse position of at least a portion of the electrode assembly. Such adjustment may be based on a determined deviation of the transverse position of the electrode assembly from a desired transverse position. The method may comprise, for example, passing the electrode assembly across an aligner (e.g. an adjustable roller or assembly of rollers), and adjustment of the transverse position of the at least a portion of the electrode assembly may comprise adjustment of the aligner.

The aligner may be upstream (i.e. relative to the direction of movement of the electrode assembly) of a location at which the transverse position of the electrode assembly is detected. The method may comprise, upon detection of the transverse position of the electrode assembly deviating from a desired position in a first direction, adjusting the aligner to move a portion of the electrode assembly at the aligner in a second direction that is opposite the first direction. In this way, detection of the transverse position of the electrode assembly and subsequent adjustment of the aligner may form a feedback loop.

The method may comprise moving a solar cell from the row of solar cells to the electrode assembly. Such movement may, for example, be performed by an automated picker (e.g. a robotic arm). As may be appreciated, this step may be repeated for each solar cell in the row of solar cells (i.e. until the electrode assembly is fully assembled with cell region provided with a solar cell positioned thereon). For example, this step may be repeated ten times to produce a solar cell string with ten solar cells.

For each movement of a solar cell to the electrode assembly, the method may comprise adjusting the movement (e.g. adjusting movement of the automated picker) to compensate for any determined deviation of the longitudinal and/or transverse position of the electrode assembly (e.g. deviation of a cell region) from a desired position. As may be appreciated, at least with respect to transverse deviations, the aligner may act to reduce larger scale/global deviation, and the automated picker may account for smaller scale/local deviations. Accordingly, the combination of these two steps may provide particularly accurate and efficient alignment between the solar cells and the cell regions of the electrode assembly.

The method may further comprise detecting a position of each solar cell in the row of solar cells (e.g. prior to moving each solar cell). The method may comprise detecting a transverse position of each solar cell. The method may comprise detecting a longitudinal position of each solar cell. The method

- may comprise, for example, detecting one or more edges (e.g. longitudinal and/or transverse edges) of each solar cell. The method may, for example, comprise determining whether (and e.g. by how much) the position (e.g. a longitudinal and/or transverse position) of a solar cell deviates from a desired position. Such detection may be performed by a vision system configured to identify (e.g. via an object
- 5 detection algorithm) a solar cell. The vision system may be configured to identify a solar cell (and e.g. determine the position of the solar cell in space, such as relative to a conveyor). The method may comprise adjusting the movement of an automated picker (e.g. robotic arm) for picking up each solar cell based on a determined deviation of the position of the solar cell.
- 10 The method may comprise arranging each solar cell on a respective cell region such that the solar cell is rotated 180 degrees (i.e. about an axis in the depth direction of the solar cell) relative to an adjacent solar cell on the electrode assembly. For example, the picker may be configured to rotate alternate solar cells (i.e. every second solar cell moved by the picker may be rotated by the picker). In other
- 15 embodiments, the solar cells in the row of solar cells may be arranged such that each solar cell is rotated 180 degrees with respect to its adjacent solar cell(s).

The method may comprise arranging the solar cells so that they are longitudinally spaced from one another (i.e. such that gaps are formed between each pair of adjacent cells). The distance between each pair of adjacent cells may be e.g. less than 7 mm.

- 20 In other embodiments, the method may comprise arranging the solar cells such that they overlap (sometimes referred to as shingled solar cells). When arranged in this manner, each cell (i.e. other than those at the ends of the row of solar cells) may have a first edge supported upon a first adjacent solar cell and a second opposite edge below (and supporting) a portion of a second adjacent solar cell.
- 25 The cells may be arranged so as to overlap by e.g. up to 1 mm.

As may be appreciated, when the solar cells are shingled (i.e. overlap), the method may comprise a further step for ensuring acceptable contact between the electrode assembly and the solar cells (because the overlapped nature of the solar cells will mean that their surfaces are not coplanar). This

30 step may, for example, involve bending the electrically conductive members of the electrode assembly. The method may comprise conforming the electrode assembly (e.g. the film arrangement) to the solar cells (such as by pressing the electrode assembly against the solar cells or by pressing the solar cells against the electrode assembly). Such steps may be performed manually (by an operator), via vacuum means, via an actuatable element, etc.

- 35 When the cells are arranged so as to overlap, it may be particularly desirable for the film arrangement of the electrode assembly to be in the form of a plurality of spaced films (which may facilitate bending of the electrically conductive members).

The method may comprise electrically connecting the conductive members to a back surface of each solar cell. Each solar cell may comprise a first (i.e., front) surface, upon which light from a radiative source (e.g., the sun) is incident during normal use, and the second (i.e., back) surface may be opposite the front surface. That is, the front surface may be configured in use to face the sun, whereas the back surface may be configured in use to face away from the sun.

Each solar cell may be a back contact solar cell (e.g. an interdigitated back contact (IBC) solar cell).

The back surface of each solar cell may comprise a plurality of longitudinally extending first contact regions. The back surface of each solar cell may further comprise a plurality of longitudinally extending second contact regions. The first and second contact regions may be spaced transversely across the back surface of the solar cell in an alternating manner.

Each solar cell may comprise a plurality of longitudinally extending first charge collectors having a first conductivity type. Each solar cell may comprise a plurality of longitudinally extending second charge collectors having a second conductivity type. The first and second charge collectors of each solar cell may be spaced transversely across the solar cell in an alternating manner.

Each first and/or second charge collector of each solar cell may be at least partially doped with a prescribed conductivity type. Each first charge collector may be an n-type charge collector (i.e. may have n-type conductivity). Each second charge collector may be a p-type charge collector (i.e. may have p-type conductivity). Each first charge collector may be an electron collector. Each second charge collector may be a hole collector.

Each first contact region may be arranged to extract charge from a respective first charge collector of the solar cell. Each first contact region may be a region of (e.g. an exposed region of) of a respective first finger portion. The solar cell may comprise a plurality of longitudinally extending first finger portions spaced transversely from one another. Each first finger portion may be in electrical contact with the respective first charge collector.

Each second contact region may be arranged to extract charge from a respective second charge collector of the solar cell. Each second contact region may be a region of (e.g. an exposed region of) of a respective second finger portion. The solar cell may comprise a plurality of longitudinally extending second finger portions spaced transversely from one another. The first finger portions may be arranged in an alternating manner with the second finger portions transversely across the solar cell. Each second finger portion may be in electrical contact with a respective second charge collector of the solar cell.

The first finger portions may form part of a first contact member. The first contact member may comprise a transversely extending base portion that connects the finger portions of the first contact member. The second finger portions may form part of a second contact member. The second contact member may

comprise a transversely extending base portion that connects the finger portions of the second contact member. The first and second contact members may be arranged in an interdigitated manner (i.e. the first finger portions being interdigitated with the second finger portions).

- 5 Each finger portion may be formed of metal (e.g. aluminium). Each contact member may be formed of metal (e.g. aluminium).

- Each solar cell may be asymmetric about a central longitudinal plane (extending in the depth direction) of the solar cell. The arrangement of first and second contact regions may be asymmetric about the  
10 central longitudinal plane. There may be the same number of first contact regions as second contact regions.

- The step of arranging the solar cells on the electrode assembly may comprise arranging each solar cell such that each first and second contact region of the solar cell is positioned on a respective conductive  
15 member of the electrode assembly. Arranging each solar cell may comprise positioning the solar cell such that, when fully assembled, the solar cell is electrically connected between first and second adjacent solar cells, or between a solar cell and a terminal. For those solar cells that are electrically connected between first and second adjacent solar cells (i.e. solar cells not at the end of the string), each solar cell may be positioned such that:

- 20 each first contact region of the solar cell is electrically connected to the first adjacent solar cell by a respective electrically conductive element that does not extend to the second adjacent solar cell; and  
each second contact region of said solar cell is electrically connected to the second adjacent solar cell by a respective electrically conductive element that does not extend to the first  
25 adjacent solar cell.

- The structure of an exemplary solar cell of the second aspect is discussed below. In other words, one or more of the solar cells of the first aspect (or all of the solar cells of the first aspect) may be as described below. The below description of the exemplary solar cell is also equally applicable to one or  
30 more of the solar cells of any other aspect (including, for example, the fourth aspect).

- The solar cell may comprise a photovoltaic element. The photovoltaic element (or layer) may define a substrate on which other layers of the solar cell are arranged (e.g., deposited). The photovoltaic element may comprise crystalline silicon (e.g., monocrystalline, or polycrystalline silicon). According to an  
35 exemplary arrangement, the photovoltaic element may define a crystalline silicon wafer which has been cut from an ingot, as will be understood by the skilled person. The solar cell may comprise a plurality of layers, or elements, including the photovoltaic element. At least one of the plurality of layers may be formed of a semiconductor material.

The solar cell may be formed from a monocrystalline silicon wafer. At least one of the constituent elements of the solar cell (e.g., the charge collector) may comprise an amorphous semiconductor material (e.g., amorphous silicon, a-Si). The substrate may be at least partially doped with a prescribed conductivity type.

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The substrate may be configured with a first conductivity type (e.g., n-type) and another element (e.g., such as an abovementioned the first or second charge collectors) may be configured with a second conductivity type (e.g., a p-type) that is opposite to the first conductivity type, and thus forms a p-n junction along with the substrate. When the semiconductor material is n-type, it may be configured to contain impurities of a group V element such as phosphor (P), arsenic (As), and antimony (Sb). When the semiconductor material is p-type, it may contain impurities of a group III element such as boron (B), gallium (Ga), and indium (In).

The substrate of the solar cell may divide the solar cell into a front portion which is forward (i.e., in front of) of the substrate, and a back portion which is rearward of the substrate. The first and second charge collectors may form part of the back portion of the solar cell (i.e. may be rearward of the substrate). The first and second charge collectors may be configured to extract charge carriers from the substrate. Each of the first charge collectors or each of the second charge collectors (e.g. whichever has the same conductivity type as the substrate) may be referred to as back surface field (BSF) layers. Each back surface field layer may be more highly doped than the substrate (of the same conductivity type as the substrate).

The front portion of the solar cell may comprise a front surface field (FSF) layer (which may be provided on a front surface of the substrate). The front surface field layer may have a different conductivity type to the substrate (e.g. the FSF layer may be doped (e.g. lightly doped) so as to have an opposite conductivity type to the substrate).

The solar cell may comprise a front passivation element (e.g. formed of  $\text{SiO}_2$ ), which may form part of the front portion of the solar cell, and which may be provided on the FSF layer. The solar cell may comprise a back passivation element, which may form part of the back portion of the solar cell, and which may be provided on the charge collectors. Each finger portion may extend through (i.e. in a depth direction of the respective solar cell) the back passivation element, to contact a respective charge collector. In other words, a portion of each finger portion (i.e. the contact region) may be exposed at the back surface of the solar cell (beyond the back passivation element).

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At least the front surface of the solar cell may be textured to form a textured surface corresponding to an uneven surface. In this instance, an amount of light incident on the solar cell may increase because of the textured surface, and thus the efficiency of the solar cell may be improved.

The solar cell may further comprise an anti-reflection element, layer, or coating, arranged on the front side of the cell. The anti-reflection layer may advantageously reduce the reflectance of light incident on the solar cell and increases selectivity of a predetermined wavelength band, thereby increasing the efficiency of the solar cell.

5

The solar cell may have a substantially rectangular front and/or back surface. At least one solar cell may comprise four straight sides arranged at right angles to each other. At least one, or each, of the corners between the sides may be square, or pointed. Alternatively, the corners may be chamfered (or rounded), so as to define a pseudo-rectangular shape. The solar cell may comprise a substantially planar structure. For example, the at least one solar cell may comprise a length and/or a width which is substantially greater than its depth. The solar cells of the solar cell string may be arranged within a common plane (i.e. once assembled). Accordingly, the width wise and lengthwise dimensions of the solar cells of the solar cell string may lie in the same plane.

10

As may be appreciated, the film arrangement may provide a mechanical connection between each conductive element and a respective solar cell (e.g. in embodiments where the film arrangement spans solar cells). In an exemplary arrangement, the film arrangement may not cover all the respective back surface of each solar cell. For example, the film arrangement may not extend completely across at least one dimension (e.g., the length and/or width) of the solar cell. Alternatively, the film arrangement (e.g. each film) may cover the entire surface of the solar cell, for example, the film arrangement (e.g. each film) may extend completely across the width and/or length of the solar cell.

20

In a third aspect, there is disclosed an electrode assembly for a solar cell string, the electrode assembly comprising:

25

a film arrangement having first and second opposite sides; and

a plurality of longitudinally extending electrically conductive elements arranged on first side of the film arrangement, the plurality of conductive elements arranged in longitudinally extending lines of conductive elements that are transversely spaced from one another, and wherein the lines of conductive elements comprise a plurality of first lines of conductive elements arranged in an alternating manner with a plurality of second lines of conductive elements;

30

a plurality of electrical disconnections, each electrical disconnection electrically disconnecting two adjacent conductive elements in the same line of conductive elements, the electrical disconnections arranged in transverse rows that are longitudinally spaced from one another so as to define a plurality of cell regions therebetween, each cell region for positioning on respective solar cell of the row of solar cells,

35

wherein the rows of electrical disconnections alternate in the longitudinal direction between:

a first row type in which each electrical disconnection is provided in a respective first line of conductive elements; and

a second row type in which each electrical disconnection is formed in a respective second line of conductive elements.

Optional features of the third aspect will now be set out. These are applicable singly or in any combination with any aspect of the disclosure.

The electrode assembly may comprise e.g. three or more rows of disconnections (i.e. so as to have at least two cell regions). The electrode assembly may comprise e.g. more than five rows of disconnections (i.e. so as to have at least four cell regions). The electrode assembly may comprise eleven disconnections. The electrode assembly may, for example, be suitable for use in a solar cell string comprising ten solar cells (each provided on a respective cell region).

Each disconnection may be in the form of a longitudinally extending gap. Each gap may, for example, have a length (in the longitudinal direction) of from 1 mm to 12 mm, or e.g. from 1 mm to 9 mm.

The electrode assembly may comprise between 30 and 60 lines of conductive elements, or e.g. 36 to 44 lines of conductive elements.

The electrode assembly may be referred to as a foil-wire electrode assembly. Each conductive element may be a wire or wire portion. Each conductive element may comprise a single integrally formed element (e.g., a wire).

The conductive elements (and lines of conductive elements) may be parallel or substantially parallel to one another. The line of conductive elements may be equally or substantially equally spaced in the transverse direction. Accordingly, the plurality of lines of conductive elements may form an array of parallel, transversely spaced (e.g., equally spaced) lines of conductive elements.

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 along which the film arrangement extends, or a plane of the surface of the solar cell upon which the conductive elements are ultimately arranged in use of the electrode assembly (e.g., the back surface of the solar cell). The depth (e.g., thickness) may be measured in a direction which is perpendicular to the same plane of the film arrangement or solar cell.

The conductive elements may be formed of an electrically conductive material, such as a metallic or metallic alloy material, which may include at least one of Ag, Al, Au, and Cu.

According to an exemplary arrangement, each of the plurality of conductive elements may comprise a coating which is configured, when in use, to solder the conductive elements to the respective surfaces of the solar cells upon which they are overlaid.

- 5 The coating (i.e., the solderable coating) may comprise an electrically conductive material having a melting point which is lower than that of a core of the conductive element. 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 Ag, Bi, Cd, 10 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.

Each conductive element may be at least partly embedded in the film arrangement.

- 15 Each electrically conductive element may span two respective cell regions. As set forth above, the rows of disconnections form cell regions therebetween, each for positioning on a respective solar cell (e.g. the back surface of a solar cell). As may be appreciated, one or more of the cell regions (e.g. all cell regions except those at opposite ends) may be disposed between respective first and second adjacent cell regions. Each of such one or more cell regions may comprise thereon:
- 20 a plurality of first electrically conductive elements, each extending from the cell region to the first adjacent cell region and not to the second adjacent cell region; and
- a plurality of second electrically conductive elements spaced transversely across said cell region in an alternating manner with the first electrically conductive elements, and wherein each second electrically conductive element extends from the cell region to the second adjacent cell region and not to the first adjacent cell region.
- 25

- Each of the first and second electrically conductive elements may extend substantially fully (longitudinally) across the cell region on which it is provided. Each first electrically conductive element may extend substantially fully (longitudinally) across the first adjacent cell region. Each second electrically conductive element may extend substantially fully (longitudinally) across the second adjacent cell region.
- 30

- Each cell region may be sized and shaped for substantially covering a surface (e.g. a back surface) of a solar cell. Each cell region may be a rectangular region. The cell regions in the row of cell regions may be longitudinally spaced from one another by transition regions. Each electrical disconnection may be disposed within a transition region.
- 35

The film arrangement may comprise a single film (i.e. a unitary film).

In other embodiments, the film arrangement may comprise a longitudinally extending row of films. The films may be spaced from one another in the longitudinal direction. Each film may be substantially rectangular. Each film may be sized and shaped for substantially covering a surface (e.g. a back surface) of a solar cell. In such embodiments, each row of disconnections may be formed at least partly  
5 between two adjacent films. Thus, each film may be between (or at least mostly between) two rows of disconnections. Each film may define a respective cell region (i.e. each cell region may be a surface of a respective film).

Thus, for example, the film arrangement may comprise one or more films that are each disposed  
10 between first and second adjacent films. Each of said one or more films may comprise thereon:

a plurality of first electrically conductive elements, each extending from said film to the first adjacent film and not to the second adjacent film; and

a plurality of second electrically conductive elements spaced transversely across said film in an alternating manner with the first electrically conductive elements, and wherein each second  
15 electrically conductive element extends from said film to the second adjacent film and not to the first adjacent film.

As may be appreciated, each film of the film arrangement (except for those at each end) may have thereon the above-described arrangement of first and second electrically conductive elements.  
20

The film arrangement (e.g. the film(s)) may be configured to be electrically insulating and/or optically transparent. The film arrangement may be configured to provide adhesion between a solar cell and the conductive elements (when the electrode assembly is positioned thereon) so that the conductive elements are correctly spaced on the solar cell after assembly. In this way, the film arrangement may  
25 facilitate correct alignment of the conductive elements with regions of a solar cell.

The film arrangement (e.g. the film(s)) may be deformable when heated to allow the conductive members (and thus conductive elements) to be at least partially embedded in the first side of the film arrangement. The film arrangement may be configured such that at least a portion of each conductive  
30 element is exposed from the film arrangement to form an electrical contact with the back surfaces of the solar cells. Alternatively, the first side of the film arrangement may be coated with an adhesive which adheres the conductive members (and conductive elements) to the film arrangement.

The film arrangement (e.g. each film) may comprise multiple layers, or may comprise a single layer.  
35

The plurality of films may be spaced longitudinally from one another. The space between each pair of adjacent films may define a transition region (i.e. as described above). Thus, the longitudinal disconnections between electrically conductive elements may be disposed in the spaces formed between adjacent films.  
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The film arrangement (and thus films) may be as described above with respect to the first aspect. Likewise, the electrically conductive elements may be as described above with respect to the first aspect. As may be appreciated, each line of electrically conductive elements may be formed from an electrically conductive member as described with respect to the first aspect.

5

In a fourth aspect of the present disclosure, there is provided a solar cell string comprising:

an electrode assembly according to the third aspect; and

a plurality of solar cells arranged on the electrode assembly, each solar cell being provided on a respective cell region of the electrode assembly so as to be electrically connected to the electrode assembly at the respective cell region.

10

Optional features of the fourth aspect will now be set out. These are applicable singly or in any combination with any aspect of the disclosure.

15 Each cell region may substantially cover a surface (e.g. a back surface) of a respective solar cell.

The conductive members may be electrically connected to a back surface of each solar cell. Each solar cell may comprise a first (i.e., front) surface, upon which light from a radiative source (e.g., the sun) is incident during normal use, and the second (i.e., back) surface may be opposite the front surface. That is, the front surface may be configured in use to face the sun, whereas the back surface may be configured in use to face away from the sun.

20

Each solar cell may be oriented so as to be rotated 180 degrees with respect to at least one adjacent solar cell (i.e. about an axis extending in the depth direction).

25

Each solar cell may be a back contact solar cell (e.g. an interdigitated back contact (IBC) solar cell).

The back surface of each solar cell may comprise a plurality of longitudinally extending first contact regions. The back surface of each solar cell may further comprise a plurality of longitudinally extending second contact regions. The first and second contact regions may be spaced transversely across the back surface of the solar cell in an alternating manner.

30

Each solar cell may comprise a plurality of longitudinally extending first charge collectors having a first conductivity type. Each solar cell may comprise a plurality of longitudinally extending second charge collectors having a second conductivity type. The first and second charge collectors of each solar cell may be spaced transversely across the solar cell in an alternating manner.

35

Each first and/or second charge collector of each solar cell may be at least partially doped with a prescribed conductivity type. Each first charge collector may be an n-type charge collector (i.e. may

have n-type conductivity). Each second charge collector may be a p-type charge collector (i.e. may have p-type conductivity). Each first charge collector may be an electron collector. Each second charge collector may be a hole collector.

- 5 Each first contact region may be arranged to extract charge from a respective first charge collector of the solar cell. Each first contact region may be a region of (e.g. an exposed region of) of a respective first finger portion. The solar cell may comprise a plurality of longitudinally extending first finger portions spaced transversely from one another. Each first finger portion may be in electrical contact with the respective first charge collector.

10

Each second contact region may be arranged to extract charge from a respective second charge collector of the solar cell. Each second contact region may be a region of (e.g. an exposed region of) of a respective second finger portion. The solar cell may comprise a plurality of longitudinally extending second finger portions spaced transversely from one another. The first finger portions may be arranged in an alternating manner with the second finger portions transversely across the solar cell. Each second finger portion may be in electrical contact with a respective second charge collector of the solar cell.

15

The first finger portions may form part of a first contact member. The first contact member may comprise a transversely extending base portion that connects the finger portions of the first contact member. The second finger portions may form part of a second contact member. The second contact member may comprise a transversely extending base portion that connects the finger portions of the second contact member. The first and second contact members may be arranged in an interdigitated manner (i.e. the first finger portions being interdigitated with the second finger portions).

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- 25 Each finger portion may be formed of aluminium. Each contact member may be formed of aluminium.

Each solar cell may be asymmetric about a central longitudinal plane (extending in the depth direction) of the solar cell. The arrangement of first and second contact regions may be arranged asymmetrically about the central longitudinal plane. Each solar cell may have the same number of first contact regions as second contact regions.

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Each first and second contact region of each solar cell may be positioned on a respective conductive member of the electrode assembly. Each solar cell may be electrically connected between first and second adjacent solar cells, or between an adjacent solar cell and a terminal. For those solar cells that are electrically connected between first and second adjacent solar cells (i.e. solar cells not at the end of the string), each solar cell may be positioned such that:

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each first contact region of the solar cell is electrically connected to the first adjacent solar cell by a respective electrically conductive element that does not extend to the second adjacent solar cell; and

each second contact region of said solar cell is electrically connected to the second adjacent solar cell by a respective electrically conductive element that does not extend to the first adjacent solar cell.

- 5 The solar cells may be arranged so that they are longitudinally spaced from one another (i.e. such that gaps are formed between each pair of adjacent cells). The distance between each pair of adjacent cells may be e.g. less than 7 mm.

- 10 In other embodiments, the solar cells may be arranged such that they overlap (sometimes referred to as shingled solar cells). When arranged in this manner, each cell (i.e. other than those at the ends of the row of solar cells) may have a first edge supported upon a first adjacent solar cell and a second opposite edge below (and supporting) a portion of a second adjacent solar cell. The cells may be arranged so as to overlap by e.g. up to 1 mm.

- 15 When the cells are arranged so as to overlap, it may be particularly desirable for the film arrangement of the electrode assembly to be in the form of a plurality of spaced films (which may facilitate bending of the electrically conductive members).

- 20 One or more of the solar cells (e.g. each solar cell) of the fourth aspect may be (i.e. may have the solar cell structure) as described above with respect to the second aspect.

In a fifth aspect of the present disclosure, there is provided a solar cell string comprising a row of electrically connected solar cells, each solar cell comprising:

- a photovoltaic element,
- 25 a plurality of longitudinally extending first contact regions, each arranged to extract charge carriers from a respective first charge collector having a first conductivity type,
- a plurality of longitudinally extending second regions, each arranged to extract charge carriers from a respective second charge collector having a second conductivity type that is different to the first conductivity type, the first and second regions spaced transversely across a back
- 30 surface of the solar cell in an alternating manner; and
- a plurality of electrically conductive elements electrically connecting the solar cell to at least one adjacent solar cell in the row of solar cells;

- wherein at least one solar cell of the plurality of solar cells is disposed between first and second adjacent solar cells, and wherein the electrically conductive elements of the at least one solar cell are arranged
- 35 such that:

each first region of said at least one solar cell is electrically connected to the first adjacent solar cell by a respective electrically conductive element that does not extend to the second adjacent solar cell; and

each second region of said at least one solar cell is electrically connected to the second adjacent solar cell by a respective electrically conductive element that does not extend to the first adjacent solar cell.

- 5 The solar cell string of the fifth aspect may be as described with respect to the fourth aspect (e.g. may include one or more optional features of the fourth aspect).

In a sixth aspect of the present disclosure, there is provided a system for positioning solar cells on an electrode assembly comprising conductive elements connecting a row of films, the system comprising:

- 10 a vision system configured to detect a position of a film of the electrode assembly; and  
an automated picker configured to position a solar cell on the film of the electrode assembly using the detected position of the detected film.

- Optional features of the sixth aspect will now be set out. These are applicable singly or in any  
15 combination with any aspect of the disclosure.

- The vision system may be configured to detect one or more edges of the film. The vision system may be configured to detect a transverse position of the film. The transverse direction may be perpendicular to the direction of extension of the row of films. The vision system may be configured to detect a  
20 longitudinal position of the film. The longitudinal direction may be parallel to the direction of extension of the row of films. The vision system (e.g. a controller operatively connected to the vision system) may be configured to determine whether (and/or by how much) the position (e.g. the longitudinal and/or transverse position) of a film deviates from a desired position. The vision system may be as otherwise described above with respect to the second aspect.

- 25 The system may comprise a conveyor for conveying the solar cells. The conveyor may be configured to convey the solar cells (e.g. towards the picker) based on the detected position of the film. The conveyor may be a conveyor belt. The conveyor may be configured to move the solar cells in a longitudinal direction.

- 30 The system may comprise a conveyor for conveying the electrode assembly. The conveyor may be a conveyor belt (e.g. a vacuum conveyor belt). The conveyor may be configured to convey the electrode assembly (e.g. towards the picker) based on the detected position of the film (e.g. based on the detected deviation of a longitudinal position of a film from a desired longitudinal position of the film). The conveyor  
35 may be configured to move the electrode assembly in a longitudinal direction.

This system may comprise an aligner. The aligner may be e.g. an adjustable roller or assembly of rollers across which the electrode assembly passes in use. The aligner may be configured to adjust a transverse position of at least a portion of the electrode assembly. The aligner may be operatively connected to the vision system (and/or the controller). The aligner may be configured to adjust the electrode assembly transversely based on the detected transverse position of a film (e.g. a determined deviation of the transverse position of the electrode assembly from a desired transverse position). The aligner may be configured to adjust the position of a film other than the detected film. The aligner may be located upstream of the automated picker (i.e. relative to the direction of movement of the electrode assembly) and may be located upstream of the detected film (i.e. the adjusted part of the electrode assembly may be different from that which is detected by the vision system).

The aligner may be configured to, upon detection (by the vision system) of the transverse position of the electrode assembly deviating from a desired position in a first direction, move a portion (e.g. a film) of the electrode assembly at the aligner in a second direction that is opposite (or substantially opposite) to the first direction.

The picker may, for example, be a robotic arm. The picker may be disposed between the conveyor for the solar cells and the conveyor for the electrode assembly. The picker may comprise e.g. a gripper for gripping (e.g. via suction) a solar cell.

The automated picker may be configured to compensate for any determined deviation of the longitudinal and/or transverse position of the electrode assembly (e.g. deviation of a cell region) from a desired position. As may be appreciated, at least with respect to transverse deviations, the aligner may act to reduce larger scale/global deviation, and the automated picker may account for smaller scale/local deviations. Accordingly, the combination of these two components of the system may provide particularly accurate and efficient alignment between the solar cells and the films of the electrode assembly.

The vision system may be a first vision system and the system may comprise a second vision system. The second vision system may be configured to detect a position of each solar cell in the row of solar cells (e.g. prior to moving each solar cell). The second vision system may be configured to detect a transverse position of each solar cell. The second vision system may be configured to detect a longitudinal position of each solar cell. The second vision system may be configured to detect one or more edges (e.g. longitudinal and/or transverse edges) of each solar cell. The second vision system (or e.g. a controller operatively connected to the second vision system) may be configured to determine whether (and e.g. by how much) the position (e.g. a longitudinal, transverse position and/or rotational angle) of a solar cell deviates from a desired position. Such detection may be performed e.g. via an object detection algorithm. The automated picker may be configured to adjust a movement thereof when picking up each solar cell based on a determined deviation of the position of the solar cell.

The system may comprise a controller for controlling at least one of the conveyors and the picker. The controller may be operatively connected to the vision system(s) for receiving data regarding detected positions from the vision system(s).

- 5 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–  
10 voltage (I-V) characteristic).

- In a seventh aspect of the present disclosure, there is provided a cutting tool for forming gaps in elongate conductive members (e.g. wires) for a solar cell electrode assembly, the cutting tool comprising a row of spaced apart blades, each blade configured to form a cut in an elongate conductive  
15 member when pressed into the elongate conductive member.

- By providing a row of spaced apart blades, the cutting tool can be used to form a pattern of electrical disconnections as described above, for example, with respect to the third aspect. That is, the cutting tool may be used to form gaps in every second elongate conductive member in a row of longitudinally  
20 extending, transversely spaced conductive members. This may be achieved by aligning each blade with a respective conductive member and also aligning each space between two neighbouring blades with a respective conductive member. In this way, when the cutting tool is pressed into the conductive members, conductive members aligned with a blade will be cut and conductive member aligned with a space will not be cut.

- 25 Optional features of the seventh aspect will now be set out. These are applicable singly or in any combination with any aspect of the disclosure.

- The cutting tool may be configured for cutting conductive members that are longitudinally extending and transversely spaced. Thus, the row of blades may extend in a transverse direction. For consistency  
30 the terms "transverse" and "longitudinal" are used herein to describe the arrangement of the blades on the cutting tool. It should, however, be appreciated that these terms are not intended to require the cutting tool to have any particular shape.

- 35 The row of blades may comprise between 10 and 50 blades, or e.g. between 15 and 30 blades, or e.g. between 18 and 22 blades.

- As may be appreciated, the blades in the row of blades may be aligned along a single axis (e.g. the transverse axis). In other embodiments the blades in the row of gap forming portions may be arranged  
40 in a staggered manner, such that the blades are not aligned on a single axis. That is, it should be

appreciated that the row of blades may not necessarily extend linearly (the row may, for example, instead extend a long a zigzag path).

5 The row of blades may extend in a row direction (the row direction may be parallel to the transverse direction). Each blade of the row of blades may have a cutting edge (i.e. an edge arranged to cut a conductive member). Each cutting edge may be oriented so as not to be perpendicular to the row direction. Each cutting edge may be oriented so as to be parallel to the row direction. Each cutting edge may be linear (i.e. straight).

10 The row of blades may be a first row of blades. The cutting tool may comprise a second row of blades. The second row of blades may be substantially parallel to the first row of blades. The second row of blades may be spaced from the first row of blades in a direction that is perpendicular to the first and/or second rows (e.g. may be spaced in the longitudinal direction). That is, the first and second rows of blades may extend alongside (but be spaced from) one another.

15 The blades of the second row of blades may be as described above with respect to the first row of blades. For example, each blade of the second row of blades may comprise a cutting edge, which may be oriented so as to be non-perpendicular to (e.g. parallel to) the row direction of the second row of blades.

20 The second row of blades may comprise between 10 and 50 blades, or e.g. between 15 and 30 blades, or e.g. between 18 and 22 blades. Thus, the cutting tool may comprise (i.e. including both the first and second rows of blades) between 20 and 100 blades, or e.g. between 30 and 60 blades, or e.g. between 36 and 44 blades.

25 Each blade of the second row of blades may be aligned (e.g. along a longitudinal extending axis) with a blade of the first row of blades. That is, the blades in the first and second rows of blades may be arranged in pairs of blades, with each pair of blades including a first blade from the first row of blades and a second blade from the second row of blades. Each pair of blades may be arranged to form two spaced apart cuts in an elongate conductive element (e.g. wire). As may be appreciated, such an arrangement of cuts can be used to form a gap in the conductive element. Thus, each pair of blades  
30 may be referred to as a gap forming portion.

The cutting tool may comprise between 10 and 50 gap forming portions, or e.g. between 15 and 30 gap forming portions, or e.g. between 18 and 22 gap forming portions.

35 In some embodiments, the first and second blades of each gap forming portion may be connected to one another (e.g. may form portions of a single structure). For example, the first and second blades may form spaced portions of e.g. a circular or square blade (or e.g. a punch).

The first and second blades of at least one (e.g. each) gap forming portion may be spaced apart (e.g. in the longitudinal direction) by a distance of less than 12 mm, or e.g. less than 9 mm. The first and second blades may be spaced apart (e.g. in the longitudinal direction) by a distance that is greater than 1 mm.

5

The cutting tool may comprise a body from which the blades extend. The body may be elongate (e.g. in the transverse direction).

The cutting tool may comprise an actuator configured to press the blades into conductive members in use. In some embodiments, the actuator may be configured to move the cutting tool linearly (i.e. towards/away from the conductive members). In other embodiments, the actuator may be configured to rotate the cutting tool (for example, the cutting tool may be in the form of a roller).

In an eighth aspect of the present disclosure, there is provided a cutting system comprising a cutting tool according to the seventh aspect and a conveyor (e.g. a belt) configured to convey a plurality of longitudinally extending, transversely spaced conductive members for cutting by the cutting tool.

The preceding summary is provided for purposes of summarising some examples to provide a basic understanding of aspects of the subject matter described herein. Accordingly, the above-described features should not be construed to narrow the scope or spirit of the subject matter described herein in any way. Moreover, the above and/or proceeding examples may be combined in any suitable combination to provide further examples, except where such a combination is clearly impermissible or expressly avoided. Other features, aspects, and advantages of the subject matter described herein will become apparent from the following text and the accompanying drawings.

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#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Aspects, features, and advantages of the present disclosure will now be described by way of example only, with reference to the appended drawings in which like numerals denote like elements.

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Figs. 1a and 1b are schematic plan views of a solar cell module including a plurality of solar cells, wherein Fig. 1a is a front view and Fig. 1b is a back view;

Fig. 2 is a close-up schematic sectional side view of the solar module of Fig. 1a, showing a first solar cell coupled to a second solar cell by an electrode assembly;

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Fig. 3 is a schematic sectional side view of part of a solar cell of the solar cell module of Fig. 1a;

Fig. 4 is a schematic top view of part of a solar cell string;

40

Fig. 5 is a schematic top view of part of an electrode assembly;

Fig. 6 is a block diagram showing an example method of forming an electrode assembly;

5 Figs. 7a and 7b are respective top and side views of a cutting tool for use in the method of Fig. 6; and

Fig 8. is a schematic view of a system for forming an electrode assembly.

## DETAILED DESCRIPTION

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Aspects and embodiments of the present disclosure will now be discussed with reference to the accompanying figures. Further aspects and embodiments will be apparent to those skilled in the art.

15 Fig. 1a and 1b show a solar cell module 100 (e.g., solar panel) according to the present disclosure. The solar cell module 100 includes a plurality of solar cells 101 (including a first solar cell 101a and a second solar cell 101b, shown in more detail in Figure 2) which are arranged within a housing 102 (e.g., a structural frame, or support) of the solar module 100, as will be described in more detail below. The solar cells 101 are sandwiched between a front plate 103 and a back plate 104 of the solar module housing 102, as is shown in Fig. 2.

20

The solar module 100 includes electrical circuitry (e.g., an electrical assembly) to enable electrical power to be extracted from the solar cells arranged inside the module housing 102. The electrical circuitry includes a pair of electrical connectors 105 (as shown in Fig. 1b) which couple the module 100 to an external circuit (e.g., two adjacent solar modules). The external connectors 105 are connected, at  
25 one end, to a junction box 106 which is arranged on the back side of the solar module 100 (e.g., mounted to the back plate 104). At least one further connector provides an electrical connection between the junction box 106 and the solar cells 101 which are arranged within the module 100 (e.g., an internal connector). The electrical circuitry may include at least one diode (e.g., bypass diodes) which regulates the flow of charge between the solar cells and/or between the solar module and the external  
30 electrical circuit. The electrical circuitry components can be arranged within the junction box and/or within the module housing itself. It will be appreciated that the solar module may comprise a plurality of connectors and/or junction boxes as appropriate.

35 The solar module 100 has a length which is the horizontal dimension of Figs. 1a and 1b, a width which is the vertical direction of Figs. 1a, 1b and 2, and a height (or thickness) which is substantially into the page of Figs. 1a, and 1b, and the vertical direction of Fig 2.

According to the exemplary arrangement shown in Fig. 1a, the solar module 100 includes ninety-six solar cells 101 arranged in a rectangular array comprising six rows and sixteen columns (arranged  
40 horizontally and vertically, in Fig. 1a, respectively). It will be appreciated that the solar module 100 may

be configured with any number of solar cells 101 (e.g., arranged in different array shapes, and comprising different numbers of columns and rows), without departing from the scope of the present disclosure. At least some of the solar cells 101 are electrically coupled together (e.g., in series) to form a solar cell string 107 (i.e. a row of solar cells in the length direction). The solar module 100 includes a plurality of solar cell strings 107. At least some of the solar cell strings 107 are electrically coupled together in series. Two or more of the strings 107 may be coupled together in parallel. Different strings 107 may be connected together using one or more cross-connectors which are mounted within the solar module housing 102.

10 The front plate 104 of the module housing 102 comprises a transparent (e.g., glass) sheet which is configured to allow light to pass through into a central chamber 108 in which the solar cells 101 are mounted. The arrows at the top of Fig. 2 show the direction of the solar radiation which is incident upon the solar module 100 during use. The back plate 104 is arranged to enclose the solar cells 101 within the central chamber 108. The back plate 104 comprises a reflective sheet which reflects any light  
15 incident upon its front surface (i.e., front facing surface) back towards the solar cells 101. The central chamber 108 is filled with an encapsulating material 113 (i.e., the shaded area shown in Fig. 2) which prevents ingress of fluid entrants which could degrade the solar module's performance.

Fig. 2 shows two of the solar cells 101a, 101b arranged as part of a solar cell string 107 according to the present disclosure that is arranged within the housing 102 of the solar module 100. In particular, Fig. 2 is a close-up schematic sectional side view of the solar module 100, taken along line A-A shown in Fig. 1a. The solar cell string 107 includes a first solar cell 101a, a second solar cell 101b and an electrode assembly 109 (described in more detail further below) which is arranged to electrically couple a back surface 110a of the first solar cell 101a to a back surface 110b of the second solar cell 101b. In  
25 fact, all the solar cells 101 of the solar cell string 107 are connected via their back surfaces. Thus, for example, the back surface 111b of the second solar cell 101b is electrically coupled to the back surface of a third solar cell (not shown) by the electrode assembly 109, and so on.

Each of the solar cells 101 has a length which is the horizontal dimension of Figure 2, a height (or thickness) which is the vertical direction of Figure 2, and a width which is substantially into the page of Figure 2. Each of the two illustrated solar cells 101a, 101b of Fig. 2 includes a front surface 112a, 112b which is the surface upon which light is incident when the solar cell string 107 is in use. The back surfaces 110a, 110b each define a surface which is opposite to the respective front surface 112a, 112b.

35 The solar cells 101 each have a substantially rectangular front and/or back surface (e.g., the solar cell comprises four straight sides arranged at right angles to each other). At least one, or each, of the corners between the sides may be square, or pointed (as shown in Fig. 2b). Alternatively, the corner may be chamfered (or rounded), so as to define a pseudo-rectangular shape. In exemplary arrangements in which the solar cells are each formed from a semiconductor wafer (e.g., a crystalline silicon wafer), then the dimensions of each solar cell may substantially correspond to that of a single  
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wafer (e.g., a whole wafer silicon cell). The solar cells may be formed from a wafer which is cut into a plurality of sections. For example, the planar wafer may be cut along an in-plane direction (e.g., a width or length direction) to define a cut solar cell (e.g., a half-cut solar cell).

- 5 The solar cells 101 are spaced apart along the same parallel transverse plane of the solar module 100 (as is apparent from the two solar cells 101a, 101b shown in Fig. 2), such that their widthwise and lengthwise dimensions lie in parallel with each other. The electrode assembly 109 extends horizontally along the back surface 110a of the first solar cell 101a and horizontally along a back surface 110b of the second solar cell 101b. The electrode assembly 109 also extends horizontally across a gap  
10 between the first 101a and second 101b solar cells.

- Each solar cell 101 includes a layered structure (as is described below in relation to Fig. 3) arranged between its respective front and back surfaces. The layered structure is a multi-layer semiconductor assembly which includes a photovoltaic element (or layer) which is configured to generate electrical  
15 charge carriers from the absorption of incident radiation. The electrode assembly 109 is configured to form an electrical connection between each solar cell's 101 layered structure and an adjacent solar cell 101 to enable extraction and transport of electrical charge carriers generated by the solar cell.

- Fig. 3 is a cross-sectional side view of a back portion of a solar cell 101 of a solar cell string 107 (forming  
20 part of the solar module 100 described above in relation to Figs. 1a to 2b). The solar cell 101 has a first (i.e., front) surface, not shown, upon which light from a radiative source (e.g., the sun) is incident during normal use, and a second (i.e., back) surface 110 that is opposite the front surface. That is, the front surface may be configured in use to face the sun, whereas the back surface 110 may be configured in use to face away from the sun.

- 25 The solar cell 101 has a generally layered structure which comprises, among other layers, a photovoltaic element which defines a semiconductor substrate 114. Various layers may be provided on the substrate 114, which may be formed by sequentially depositing the constituent layers onto respective front and back surfaces of the substrate 114. Each of such layers may be configured with a  
30 width, a length, and a depth. The width and length of each layer is measured in perpendicular directions that are aligned with the front and back surfaces of the substrate 114. For each layer, each of its width and length is substantially greater than its depth, which is measured in a direction that is perpendicular to the front and back substrate surfaces.

- 35 In the illustrated embodiment, the back surface of the substrate 114 is provided with a plurality of charge collection elements/layers (e.g., charge collectors) 115, 116 thereon, which are configured to extract charge carriers from the substrate 114. In particular, the solar cell 101 is provided with a plurality of electron-collectors 115 (two of which are shown) and plurality of a hole-collectors 116 (only one of which is shown), which are both arranged at the back surface 110 of the substrate 114.

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The substrate 114 is formed of crystalline silicon (c-Si), e.g., monocrystalline, polycrystalline silicon. According to the illustrated example, the substrate 114 is an n-type monocrystalline silicon wafer which forms a p-n junction with the p-type hole-collectors 116. The electron-collectors 115 are doped to be n-type, such that it is configured to extract electrons from the substrate 114. The electron and hole collectors 115, 116 are each formed of hydrogenated amorphous silicon (a-Si:H) material, which is doped with corresponding elements in order to achieve the prescribed conductivity type, as would be understood by the skilled person. The electron-collectors 115 and hole-collectors 116 each extend longitudinally (i.e. in the length direction) across the back surface of the substrate 114 (i.e. at the back surface 110 of the solar cell 101). In particular, the electron-collectors 115 and hole-collectors 116 are arranged in an alternating manner in a transverse direction across the rear surface of the substrate 114.

The aid in the extraction of charge carriers from the solar cell 101, the solar cell 101 further comprises a plurality of longitudinally extending first 123a and second 123b aluminium finger portions arranged in an alternating manner transversely across the back portion of the solar cell 101 (i.e. rearward of the substrate 114). In particular, each finger portion 123a, 123b is in contact with a back surface of a respective charge collector 115, 116. Each of the finger portions 123a, 123b includes a respective longitudinally extending first 124a or second 124b contact region. In this way, the solar cell 101 includes a plurality of first 124a and second 124b longitudinally extending contact regions arranged in an alternating manner transversely across a back surface of the solar cell 101.

Although not apparent from the figure, each first finger portion 123a forms part of a first contact member that further includes a base portion extending transversely so as to join respective ends of the first finger portions 123a. Each second finger portion 123b forms part of a first contact member that further includes a base portion extending transversely so as to join respective ends of the second finger portions 123b. The first and second contact member oppose one another such that the first 123a and second 123b finger portions are arranged in an interdigitated manner.

To extract charge from the solar cell 101, the solar cell 101 is provided with an electrode assembly 109. This is provided on the back surface 110 of the solar cell 101. The electrode assembly 109 comprises longitudinally extending electrically conductive elements 117a, 117b (which, in this embodiment are in the form of wires, e.g. copper wires) and a film 118. The film 118, which may be formed of a polymeric material, is provided rearward of the electrically conductive elements 117a, 117b (such that the electrically conductive elements 117a, 117b are sandwiched between the back surface 110 of the solar cell 101 and the film 118). The plurality of conductive elements 117a, 117b are spaced transversely from one another and include first 117a and second 117b conductive elements arranged in an alternating manner transversely across the back surface 110 of the solar cell 101. Each first conductive element 117a is positioned on a respective first contact region 124a (so as to extract charge from a respective electron-collector 115) and each second conductive element 117b is positioned on a respective second contact region 124b (so as to extract charge from a respective hole-collector 116). Each conductive element 117a, 117b extends longitudinally along the respective electron-collector 115

or hole-collector 116). Each conductive element 117a, 117b is thus electrically connected (via a respective finger portion 123a, 123b) with a respective collector 115, 116 for the extraction of electrical charge (which can then be transported to adjacent solar cells 101).

- 5 The solar cell 101 further includes a back passivation layer 125 which extends across the back surfaces of the charge collectors 115, 116. The back passivation layer includes openings through which the finger portions 123a, 123b extend to allow each finger portion to have a front surface in contact with a respective charge collector 115, 116, and a back surface (defining the contact regions 124a, 124b) that is exposed beyond the passivation layer for contact with a respective conductive element 117a, 117b.

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Figure 4 illustrates how the conductive elements 117a, 117b are arranged so as to transport charge along a solar cell string 107. This figure illustrates a solar cell 101 of the solar cell string 107 that is positioned between first 101' and second 101'' adjacent solar cells of the solar cell string 107. Also apparent from this figure is the arrangement of electrically conductive elements 117a, across the back surfaces 110 of the three solar cells 101, 101', 101'' of the solar cell string 107 to connect the solar cells 101, 101', 101''. As may be appreciated, the illustrated pattern of conductive elements 117a, 117b repeats along the solar cell string 107.

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- The electrically conductive elements 117a, 117b extend longitudinally (so as to be parallel with one another) and are spaced transversely from one another across the back surfaces 110 of the solar cell 101. The plurality of conductive elements 117a, 117b includes first conductive elements 117a and second conductive elements 117b, which are arranged in an alternating manner. Each first conductive element 117a is arranged to extract charge carriers from an n-type electron-collector 115 (i.e. via a first finger portion 123a as shown in Figure 3) and each second conductive element 117b is arranged to extract charge carriers from a p-type hole-collector 116 (i.e. via second finger portion 123b) of the solar cell 101. Each of the first 117a and second 117b conductive elements extends substantially fully across the length (i.e. in the longitudinal direction) of the solar cell 101.

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- Each first conductive element 117a extends longitudinally from the solar cell 101 to the first adjacent solar cell 101' but does not extend to the second adjacent solar cell 101''. Each first conductive element 117a extends substantially fully across the length of the first adjacent solar cell 101'. In this way, each first conductive element 117a electrically connects the solar cell 101 to the first adjacent solar cell 101'.

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- Each second conductive element 117b extends longitudinally from the solar cell 101 to the second adjacent solar cell 101'' but does not extend to the first adjacent solar cell 101'. Each second conductive 117b element extends substantially fully across the length of the second adjacent solar cell 101''. In this way, each second conductive element 101'' electrically connects the solar cell 101 to the second adjacent solar cell 101''.

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Accordingly, each conductive element 117a, 117b (whether a first or second conductive element) spans two solar cells 101, 101', 101'' and connects a first finger portion 115 (arranged to extract charge from an n-type electron-collector 115) of one solar cell and a second finger portion 116 (arranged to extract charge from a p-type a hole-collector 116) of another solar cell.

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Although not apparent from the figure, each of the first 101' and second 101'' adjacent solar cells is identical to the solar cell 101 but is rotated 180 degrees with respect to the solar cell 101 (i.e. about an axis extending in the depth direction). As a result of this, and as a result of the positioning of the first 123a and second 123b finger portions (and electron-collectors 115 and hole-collectors 116) of the solar cells 101, 101', 101'', each conductive element 117a, 117b electrically connects an electron collector 115 of one solar cell 101, 101', 101'' to a hole-collector 116 of another solar cell 101, 101', 101''. In other words, each first conductive element 117a extends from a first contact region 124a of the solar cell 101 to a second contact region 124b of the first adjacent solar cell 101'. Each second conductive element 117b extends from a second contact region 124b of the solar cell 101 to a first contact region 124a of the second adjacent solar cell 101''.

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As may be appreciated, the described arrangement of conductive elements 117a, 117b is formed by way of the formation of a plurality of electrical disconnections 119, which are in the form of longitudinal gaps. As will be described further below, these disconnections 119 divide a plurality of longitudinally extending, transversely spaced, conductive members 120a, 120b to form lines of conductive elements 117a, 117b (which are thus electrically insulated from other conductive elements 117a, 117b of the same conductive member 120a, 120b).

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The conductive members 120a, 120b include a plurality of first conductive members 120a and second conductive members 120b arranged in an alternating manner in the transverse direction. The disconnections 119 are arranged in rows 121a, 121b of disconnections 119. In particular, a first row 121a of disconnections 119 is provided between (i.e. in the gap between) the solar cell 101 and the first adjacent solar cell 101'. Each disconnection 119 in the first row of disconnections is formed in a first conductive member 120a. In this way, moving transversely across the conductive members (or lines of conductive elements) 120a, 120b, every second conductive member 120a, 120b includes a disconnection 119. A second row 121b of disconnections 119 is provided between (i.e. in the gap between) the solar cell 101 and the second adjacent solar cell 101''. In this way, the second row 121b of disconnections 119 is longitudinally spaced from the first row 121a of disconnections 119. Each disconnection 119 in the second row 121b of disconnections 119 is formed in a second conductive member 120b. As may be appreciated, this pattern of first 121a and second rows 121b of disconnections 119 is repeated for each solar cell 101 in the solar cell string 107.

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The solar cell string 107 further comprises a film arrangement, which in the illustrated embodiment is in the form of a plurality of films 118, each provided on a respective solar cell 101, 101', 101''. Each film 118 substantially covers the back surface 110 of a respective solar cell 101, 101', 101'' such that the

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portions of the conductive elements 117a 117b on the back surface 110 are received between the back surface 110 and the film 118 (as discussed with respect to Figure 3).

5 In other embodiments, the film arrangement may, for example, be formed of a single unitary film that extends across all of the solar cells 101 in a solar cell string 107. Such an arrangement is depicted in Figure 5, which shows an electrode assembly 109 prior to placement on a solar cell string 107. The electrode assembly 109 includes a longitudinally spaced row of cell regions (depicted with dashed lines) including a cell region 122 that is disposed between a first adjacent cell region 122' and a second adjacent cell region 122". Each cell region is for positioning on the back surface of a respective solar  
10 cells.

The electrode assembly includes the same arrangement of electrically conductive members 120a, 120b, disconnections 119 and conductive elements 117a, 117b as described above (and for that reason, the same reference numerals have been used). Thus, for example, each first electrically  
15 conductive element 117a of the cell region 122 extends to the first adjacent cell region 122' but not to a second adjacent cell region 122". Likewise, each second electrically conductive element 117b of the cell region 122 extends to the second adjacent cell region 122" but not to the first adjacent cell region 122'. Further, first 121a and second 121b longitudinally spaced (and transversely extending) rows of disconnections 119 are provided either side of the cell region 122. Each disconnection 119 in the first  
20 row 121a is formed in a first conductive member 120a and each disconnection 119 in the second row 121b is formed in a second conductive member 120b.

Figure 6 illustrates a method 200 of forming an electrode assembly, such as those described above with respect to Figures 4 or 5. The method comprises first providing a film arrangement (whether in the  
25 form of a single film or a plurality of separate films) in step 201. The film arrangement (formed of a plurality of films or a single unitary film) has first and second opposite sides (i.e. each providing a major surface of the film). A plurality of longitudinally extending, transversely spaced, conductive members 120a, 120b are then positioned (in step 202) on the first side of the film arrangement (which will ultimately then be positioned on the back surfaces of solar cells of a solar cell string). The nature of the  
30 film of the film arrangement is such that it at least partly adheres to the conductive members 120a, 120b, which helps to retain the conductive members 120a, 120b in their desired positions. The plurality of conductive members 120a, 120b comprises first 120a and second 120b conductive members arranged in an alternating manner as already described above.

35 A first cutting action is then performed in step 203, in which disconnections 119 (e.g. gaps) are formed in a selection of the conductive members 120a, 120b. In particular, the disconnections 119 are formed as a first transversely 121a extending row of disconnections 119. Each disconnection 119 of the first row 121a is formed in a first conductive member 120a (i.e. the second conductive members 120b are not cut in the first cutting action). As may be appreciated, the first cutting action could instead comprise  
40 forming disconnections 119 in the second conductive members 120b. The cutting action of step 203 is

performed by a cutting tool, which may be of the type shown in Figure 7 (and which will be described in further detail below). Cutting each conductive member 120a to form disconnections 119 divides the conductive member 120a into a series of colinear conductive elements 117a, 117b.

5 As may be appreciated, the way in which the disconnections 119 of the embodiment of Figure 5 are formed must take into the fact that the conductive member 120a, 120b are positioned on top of the film arrangement at the locations that such cuts must be made. Making two longitudinally spaced apart cuts to form a disconnection 119 may not be sufficient in the embodiment of Figure 5, because the portion between the cuts will remain affixed to the film arrangement (rather than being removed entirely as in  
10 Figure 4). Instead, disconnections 119 in the embodiment of Figure 5 may be formed by cutting through both the respective conductive member 120a, 120b and the film arrangement (i.e. so as to form an aperture in the film arrangement below the disconnection 119). Alternatively, each disconnection 119 may be formed by cutting using a thick blade to ensure the cut ends are spaced from one another after the cutting action.

15 The conductive members 120a, 120b (along with the film arrangement) are then moved in a longitudinal direction relative to the cutting tool (in step 204). As should be appreciated, either the cutting tool or the conductive members 120a, 120b (or both) can be moved to provide the relative movement. For example, the conductive members 120a, 120b and film arrangement may be conveyed on a  
20 longitudinally extending belt. The belt may move in a continuous manner (i.e. may move concurrently as the cutting action is performed).

Subsequent to the moving operation of step 204, a second cutting action is performed (at step 205). In the second cutting action, a second row of disconnections 119 (e.g. gaps) is formed in the conductive  
25 members 120a, 120b. In particular, each disconnection 119 in the second row 121b of disconnections 119 is formed in a respective second conductive member 120b. Disconnections 119 are not formed in the first conductive members 120a in the second cutting action at step 205. To achieve this, the cutting tool may be moved transversely such that e.g. blades of the cutting tool are positioned over the second conductive members 120b rather than the first conductive members 120a.

30 The movement of the conductive members 120a, 120b in the first moving operation (at step 204) means that the first 121a and second 121b rows of disconnections 119 are longitudinally spaced from one another. In particular, the disconnections 119 are spaced by approximately the length of a solar cell 101. In this way, the first 121a and second 121b rows of disconnections 119 are spaced either side of  
35 a cell region 122 for positioning on the back surface 110 of a solar cell 101 when assembled.

In other embodiments, the first and second cutting actions (at steps 203 and 205 respectively) may instead be performed together, with no moving operation between these steps. In such embodiment, for example, two cutting tools may be provided: one forming the first row 121a of disconnections 119  
40 and another forming the second row 121b of disconnections 119.

Once the second cutting action has been performed (at step 205), a further move action may be performed (at step 206) to move to the next position for performing a further cutting action (at step 207). These steps are repeated, each time altering the transverse positions of the cutting tool to form a first  
5 121a or second 121b row of disconnections 119. This results in an electrode assembly (at step 210) having the pattern of conductive elements 117a, 117b as described above with respect to Figures 4 and 5.

Figures 7a and 7b illustrate a cutting tool 300 that may be used to provide the cutting actions described  
10 in the method of Figure 6. The cutting tool 300 includes a body 301 and a plurality of blades 302 extending from an underside of the body 301. The blades 302 are arranged in pairs 303 (or "gap forming portions"). The blades 302 in a pair of blades 303 are longitudinally spaced from one another on opposite lateral sides of the body 301. The pairs of blades 303 are spaced transversely along the body 301. For the avoidance of doubt, the terms "longitudinally" and "transversely" are used here in a  
15 consistent manner with the embodiments described above. Thus, the transverse direction is the direction along the body 301 (because the body 301 extends transversely across conductive members in use). Likewise, the longitudinal direction is the direction that would be along the conductive members in normal use of the cutting tool.

20 In use, each pair of blades 303 cuts through a respective conductive member 120a, 120b to form a longitudinally extending gap 119 (between the blades 302 of the pair of blades 303). The use of two blades 303 ensures the formation of a gap 119 such that there is no electrical contact between the two resulting conductive elements 117a 117b spaced either side of the gap 119.

25 The blades 303 are arranged in two rows 304 of spaced apart blades 303. Each row 304 of spaced apart blades 303 extends in a row direction 305 (i.e. the vertical direction on the page). Each blade 303 has a linear cutting edge 306 (i.e. an edge arranged to cut a conductive member) that is distal from the body 301. Each cutting edge 306 is oriented so as to be parallel to the row direction 305. The transverse spacing of the pairs of blades 303 (i.e. taken from their centres) is approximately twice  
30 the spacing between the conductive members 120a, 120b (again, taken from their centres) of the electrode assembly 109. Accordingly, the cutting tool 300 only cuts every second conductive member 120a, 120b (moving in the transverse direction of the electrode assembly 109) in a single cutting action. This allows the cutting tool 300 to form the rows of disconnections 121a, 121b as described above.

35 When used to form disconnections 119, either a single such cutting tool 300 may be provided or at least two cutting tools 300 may be provided. When a single cutting tool 300 is provided the cutting tool 300 may be moved transversely (by a distance equivalent to the spacing between two conductive members 120a, 120b) between cutting actions to provide first 121a and second 121b rows of disconnections 119. When two cutting tools 300 are provided they may be spaced longitudinally and offset from one another

in the transverse direction (by a distance equivalent to the spacing between two conductive members 120a, 120b) to provide first 121a and second 121b rows of disconnections 119.

Figure 8 illustrates a system 400 for assembly solar cells 101 onto an electrode assembly 109 of the type shown in Figure 4 or 5. The system includes first 401 and second 402 longitudinally extending conveyor belts that are spaced laterally from one another. A plurality of solar cells 101 are arranged in a longitudinally spaced apart manner on the first belt 401. An electrode assembly 109 is provided on the second belt 402. The electrode assembly 109 includes a plurality of longitudinally spaced films 118 and a plurality of electrically conductive elements 117a, 117b that are arranged in the manner described previously (for example with respect to Figure 4 and 5).

The system 400 also comprises an automated (e.g. robotic) picker 403 (in this case, positioned between the belts 401, 402) configured to move solar cells 101 from the first belt 401 to the second belt 402. Each belt 401, 402 is configured to move in a longitudinal direction. In this case, each belt 401, 402 moves in the same direction (vertically up the page as illustrated), but the belts 401, 402 may move in opposite directions.

The picker 403 is, in particular, configured to grip (e.g. by suction) a solar cell 101 at the end of the row of solar cells 101 provided on the first belt 401 and move the solar cell 101 to the second belt 402. The picker 403 is further configured to position, and release, the "picked" solar cell 101 on the conductive elements 117a, 117b of a film (or cell region) of the electrode assembly 109 (i.e. between two rows 121a, 121b of disconnections 119). This action is repeated by the picker 403 to assemble a complete solar cell string 107. This is facilitated by the longitudinal movement of the belts 401, 402, such that each time a solar cell 101 is assembled a further solar cell 101 is delivered to the picker 403, and an open (i.e. not yet assembled with a solar cell 101) film/cell region is positioned adjacent to the picker 403.

Although in the illustrated embodiment the solar cells 101 are longitudinally spaced from one another, it should be appreciated that in other embodiments the solar cells 101 may overlap (i.e. may be shingled). In such embodiments, the system 400 may further be configured to conform the electrode assembly 109 to the overlapped solar cells 101, including e.g. bending the conductive element 117a, 117b (i.e. to better conform the conductive elements 117a, 117b to the shape of the overlapped solar cells 101). For example, the system 400 may comprise vacuum means or an actuatable element to draw/press the electrode assembly 109 onto the solar cells 101. This may be performed on the belt 402, or after removal of the solar cells string from the belt 402. Likewise, conforming the electrode assembly 109 to the overlapped solar cells 101 may otherwise be performed manually (e.g. by an operator).

As may be appreciated, in assembling the solar cells 101 on the electrode assembly 109, it is important that each solar cell 101 is aligned so that the first 124a and second 124b contact regions provided on

the back surface 110 are aligned with the correct conductive elements 117a, 117b. Misalignment could result, for example, in a short circuit. Such misalignment may be especially problematic when the electrode assembly 109 is of the type that includes a film 118 for each solar cell 101. In this case there can be deviations in the longitudinal spacing of the films 118, or deviations in the transverse positioning of the films 118 (and thus deviations in the positioning of the conductive elements 117a, 117b).

To accommodate for such deviations, the system 400 includes a first vision system 404. The first vision system 404 is configured to detect the position of each film 118 on the second belt 402 and to communicate position information to a controller 405. The controller 405 is configured to adjust the movement of the picker 403, and movement (e.g. speed) of the belts 401, 402 to account for any deviation of the film 118 from an expected position. The controller 405 is also configured to adjust an aligner 407 (in the form of a tiltable roller) that, when adjusted, moves a portion of the electrode assembly 109 (i.e. the portion adjacent the aligner) transversely. In particular, the aligner 407 is adjusted based on a detected (by the first vision system 404) deviation of the transverse position of a film 118 (i.e. the film that is next in line for receipt of a solar cell 101) from a desired transverse position. In this way, the electrode assembly 109 can be maintained in a desirable transverse position via a feedback loop between the first vision system 404 that the aligner 407.

The adjustment of movement of the belts 401 402, the picker 403 and the aligner 407 in this way, can ensure that each solar cell 101 is positioned accurately on a respective film 118.

In the present embodiment, a second vision system 406 is also provided which ensures that each solar cell 101 is accurately picked by the automated picker 403. The second vision system 406 is arranged to determine the position of each solar cell 101 on the first belt 401 (i.e. as it comes into the view of the second vision system 406). The controller 405 is operatively connected to the second vision system 406 and is configured to control the automated picker 403 to adjust the movement of the automated picker 403 based on the detected position of each solar cell 101 (i.e. to ensure accurate picking of the solar cells).

It is to be understood that the present disclosure is not limited by specific construction details or process steps set forth in the following description and accompanying drawings. Rather, it will be apparent to those skilled in the art having the benefit of the present disclosure that the systems, apparatuses and/or methods described herein could be embodied differently and/or be practiced or carried out in various alternative ways.

Unless otherwise defined herein, scientific and technical terms used in connection with the presently disclosed inventive concept(s) shall have the meanings that are commonly understood by those of ordinary skill in the art, and known techniques and procedures may be performed according to conventional methods well known in the art and as described in various general and more specific references that may be cited and discussed in the present specification.

All examples implementing the present disclosure can be made and executed without undue experimentation in light of the present disclosure. While particular examples have been described, it will be apparent to those of skill in the art that variations may be applied to the systems, apparatus,  
5 and/or methods and in the steps or in the sequence of steps of the methods described herein without departing from the concept, spirit, and scope of the inventive concept(s). All such similar substitutions and modifications apparent to those skilled in the art are deemed to be within the spirit, scope, and concept of the inventive concept(s) as defined by the appended claims.

10 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 "directly on" another element, there are no intervening elements present.

15 The use of the term "a" or "an" in the claims and/or the specification may mean "one," as well as "one or more," "at least one," and "one or more than one." As such, the terms "a," "an," and "the," as well as all singular terms, include plural referents unless the context clearly indicates otherwise. Likewise, plural terms shall include the singular unless otherwise required by context.

20 The use of the term "or" in the present disclosure (including the claims) is used to mean an inclusive "and/or" unless explicitly indicated to refer to alternatives only or unless the alternatives are mutually exclusive. For example, a condition "A or B" is satisfied by any of the following: A is true (or present), and B is false (or not present), A is false (or not present), and B is true (or present), and both A and B  
25 are true (or present).

As used in this specification and claim(s), the words "comprising," "having," "including," or "containing" (and any forms thereof, such as "comprise" and "comprises," "have" and "has," "includes" and "include," or "contains" and "contain," respectively) are inclusive or open-ended and do not exclude additional,  
30 unrecited elements or method steps.

Unless otherwise explicitly stated as incompatible, or the physics or otherwise of the embodiments, examples, or claims prevent such a combination, the features of examples disclosed herein, and of the claims, may be integrated together in any suitable arrangement, especially ones where there is a  
35 beneficial effect in doing so. This is not limited to only any specified benefit, and instead may arise from an "ex post facto" benefit. This is to say that the combination of features is not limited by the described forms, particularly the form (e.g., numbering) of example(s), embodiment(s), or dependency of claim(s). Moreover, this also applies to the phrase "in one embodiment," "according to an embodiment," and the like, which are merely a stylistic form of wording and are not to be construed as limiting the following  
40 features to a separate embodiment to all other instances of the same or similar wording. This is to say,

a reference to 'an,' 'one,' or 'some' embodiment(s) may be a reference to any one or more, and/or all embodiments, or combination(s) thereof, disclosed. Also, similarly, the reference to "the" embodiment may not be limited to the immediately preceding embodiment. Further, all references to one or more embodiments or examples are to be construed as non-limiting to the claims.

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**CLAIMS**

1. A method of forming an electrode assembly for electrically connecting a row of solar cells, the method comprising:
  - 5 providing a longitudinally extending film arrangement having first and second opposite sides;
   
arranging a plurality of longitudinally extending, transversely spaced, electrically conductive members on the first side of the film arrangement, the plurality of conductive members comprising a plurality of first conductive members arranged in an alternating manner transversely across the film arrangement with a plurality of second conductive members; and
   
10 forming a plurality of electrical disconnections in the conductive members to divide each conductive member into a plurality of electrically conductive elements, the electrical disconnections arranged in transverse rows that are longitudinally spaced from one another so as to define a plurality of cell regions therebetween, each cell region for positioning on a respective solar cell of the row of solar cells,
   
15 wherein the rows of electrical disconnections alternate in the longitudinal direction between:
    - a first row type in which each electrical disconnection is formed in a respective first conductive member; and
    - a second row type in which each electrical disconnection is formed in a respective second conductive member.
- 20 2. The method according to claim 1 wherein each disconnection is a longitudinally extending gap formed in an electrically conductive member of the plurality of electrically conductive members.
3. The method according to claim 2 comprising forming each disconnection by cutting through a
   
25 respective electrically conductive member of the plurality of electrically conductive members.
4. The method according to claim 3 comprising forming each disconnection by cutting through a
   
respective electrically conductive member of the plurality of electrically conductive members at
   
two longitudinally spaced apart locations on the respective conductive member.
- 30 5. The method according to claim 4 wherein the step of cutting through the respective conductive member is performed using a cutting tool comprising a row of transversely spaced apart blades.
6. The method according to claim 5 wherein the row of blades is a first row of blades and the
   
35 cutting tool comprises a second row of blades longitudinally spaced from the first row of blades, each blade in the first row being aligned along a longitudinal axis with a respective blade in the second row of blades.

7. The method according to any one of claims 2 to 6 wherein each gap has a length, in the longitudinal direction, of between 1 and 12 mm.
8. The method according to any one of the preceding claims comprising forming the disconnections of each row of disconnections concurrently.
9. The method according to any one of the preceding claims wherein the film arrangement comprises a longitudinally extending row of films.
10. The method according to claim 9 wherein each film is between two rows of disconnections.
11. A method of forming a solar cell string, the method comprising:  
forming an electrode assembly according to the method of any one of the preceding claims;  
and  
arranging a plurality of solar cells on the electrode assembly, each solar cell being arranged on a respective cell region of the electrode assembly so as to be electrically connected to the electrode assembly at the respective cell region.
12. The method according to claim 11 comprising detecting a position of each cell region in space.
13. The method according to claim 12 wherein the step of arranging the plurality of solar cells on the electrode assembly, comprises positioning each solar cell on a cell region using the detected position of the cell region.
14. The method according to any one of claims 12 or 13 comprising moving the electrode assembly, and wherein the movement of the electrode assembly is adjusted in response to the detected position of a cell region.
15. The method according to any one of claims 12 to 14, when dependent on claim 9, comprising moving at least a portion of the electrode assembly in a direction that is transverse to the row of films in response to the detected position of a cell region.
16. The method according to any one of claims 11 to 15 comprising arranging each solar cell on a respective cell region such that the solar cell is rotated 180 degrees relative to an adjacent solar cell on the electrode assembly.
17. The method according to any one of claims 11 to 16 wherein each cell is a back contact solar cell.
18. An electrode assembly for a solar cell string, the electrode assembly comprising:

a film arrangement having first and second opposite sides; and

a plurality of longitudinally extending electrically conductive elements arranged on first side of the film arrangement, the plurality of conductive elements arranged in longitudinally extending lines of conductive elements that are transversely spaced from one another, and wherein the  
5 lines of conductive elements comprise a plurality of first lines of conductive elements arranged in an alternating manner with a plurality of second lines of conductive elements;

a plurality of electrical disconnections, each electrical disconnection electrically disconnecting two adjacent conductive elements in the same line of conductive elements, the electrical  
10 disconnections arranged in transverse rows that are longitudinally spaced from one another so as to define a plurality of cell regions therebetween, each cell region for positioning on a respective solar cell of the row of solar cells,

wherein the rows of electrical disconnections alternate in the longitudinal direction between:

a first row type in which each electrical disconnection is provided in a respective first  
line of conductive elements; and

15 a second row type in which each electrical disconnection is formed in a respective second line of conductive elements.

19. The electrode assembly according to claim 18 comprising between 30 and 60 lines of  
conductive elements.

20. The electrode assembly according to claim 18 or 19 wherein the film arrangement comprises a  
longitudinally extending row of films, each film defining a respective cell region.

21. The electrode assembly according to claim 20 wherein each row of disconnections is formed  
25 at least partly between two adjacent films in the row of films.

22. A solar cell string comprising:

an electrode assembly according to any one of claims 18 to 21; and

30 a plurality of solar cells arranged on the electrode assembly, each solar cell being provided on a respective cell region of the electrode assembly so as to be electrically connected to the electrode assembly at the respective cell region.

23. The solar cell string according to claim 22 wherein each solar cell is oriented so as to be rotated  
180 degrees with respect to at least one adjacent solar cell.

24. The solar cell string according to claim 22 or 23 wherein each solar cell is a back contact solar  
cell.

25. The solar cell string according to claim 24 wherein each solar cell comprises a plurality of longitudinally extending first charge collectors and a plurality of longitudinally extending second charge collectors that are arranged in an alternating manner transversely across the solar cell, and wherein the first charge collectors have a different conductivity type to the first charge collectors.
26. The solar cell string according to claim 25 wherein each solar cell has the same number of first charge collectors as second charge collectors.
27. A system for positioning solar cells on an electrode assembly comprising conductive elements connecting a row of films, the system comprising:  
a vision system configured to detect a position of a film of the electrode assembly; and  
an automated picker configured to position a solar cell on the film of the electrode assembly using the detected position of the detected film.
28. The system according to claim 27 wherein the vision system is configured to detect a transverse position of the detected film, and wherein the system further comprises an aligner configured to adjust a position of at least one film of the row of films based on the detected transverse position.
29. The system according to claim 28 wherein the aligner comprises an adjustable roller across which the electrode assembly passes.
30. The system according to any one of claims 27 to 29 comprising a conveyor for conveying the electrode assembly towards the automated picker.
31. The system according to 30 wherein the conveyor comprises a vacuum conveyor belt.
32. The system according to claim 30 or 31, when dependent on claims 28, wherein the aligner is positioned upstream of the automated picker relative to a direction of movement of the conveyor towards the automated picker.
33. The system according to any one of claims 30 to 32 wherein the conveyor is configured to convey the electrode assembly based on the detected position of the film.
34. A cutting tool for forming gaps in elongate conductive members for a solar cell electrode assembly, the cutting tool comprising a row of between 10 and 50 spaced apart blades, each blade configured to form a cut in an elongate conductive member when pressed into the elongate conductive member.

35. A cutting tool according to claim 34, wherein the row of spaced apart blades extends in a row direction, and wherein each blade in the row of spaced apart blades has a cutting edge that is oriented so as not to be perpendicular to the row direction.
- 5 36. A cutting tool according to claim 34 or 35 wherein the row of blades is a first row of blades and the cutting tool further comprises a second row of blades spaced from and extending alongside the first row of blades, wherein each blade of the second row of blades is aligned with a blade of the first row of blades to form a pair of blades for forming a gap in a conductive element when pressed into the conductive element.
- 10 37. A cutting tool according to any one of claims 34 to 36 comprising an actuator configured to press the blades into conductive members in use.
- 15 38. A cutting system comprising a cutting tool according to any one of claims 34 to 37 and a conveyor configured to convey a plurality of longitudinally extending, transversely spaced conductive members for cutting by the cutting tool.