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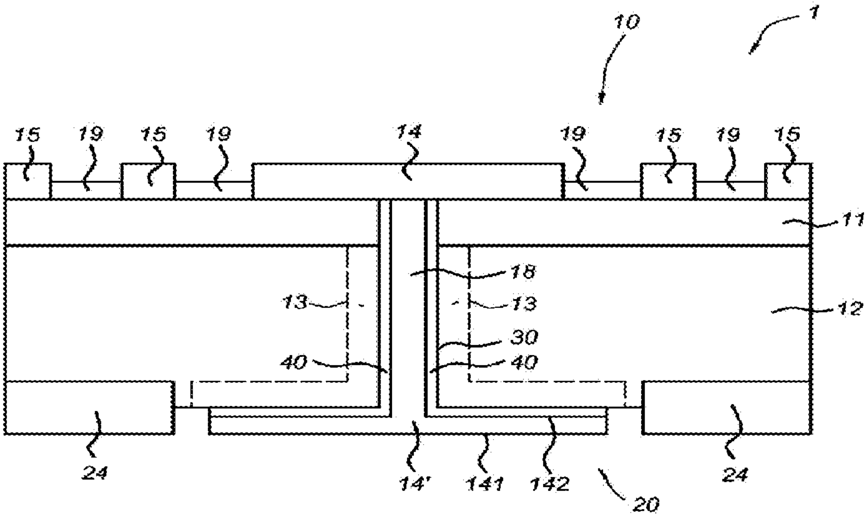
(54) **Solar cell and method of manufacturing such a solar cell.**

(57) The invention relates to a solar cell (1) comprising an emitter layer (11) at a front side (10) and a base layer (12) at the rear side (20). The solar collects first charge carriers at the front side (10) and second charge carriers at the rear side (20). The solar cell (1) further comprises at least one collecting point (14') provided at the rear side (20) and a corresponding electrical conducting path to guide the first charge carriers from the front side (10) to the at least one collecting point (14'). An insulating layer (40) is provided between at least part of the electrical conducting path and the base layer (12) to provide electrical insulation between the electrical conductive path and the base layer (12).



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SOLAR CELL AND METHOD OF MANUFACTURING SUCH A SOLAR CELL

TECHNICAL FIELD

The present invention relates to a solar cell and method of manufacturing such a solar cell. The invention specially relates to solar cells comprising collecting points at the rear side to collect charge carriers associated with the front side, such as metal wrap through solar cells, metal wrap around solar cells and emitter wrap through solar cells.

STATE OF THE ART

Different types of solar cells are known from the state of the art. An example of a prior art solar cell 1 is schematically shown in Fig. 1a.

Solar cells are usually formed as a plate, comprising a front side 10 and a rear side 20. During use, the front side 10 is orientated towards incoming (sun-)light. The front side 10 is arranged to collect light and to reflect as little light as possible.

The solar cell 1 comprises a semiconductor substrate as base material, positioned in between the front side 10 and rear side 20 of the solar cell 1. The semiconductor substrate may be made of silicon. Such solar cells may have a typical thickness of 50 – 350 μm.

The semiconductor substrate may comprise a base layer 12 of a first conductivity type and an emitter layer 11 covering the base layer on the front side of a conductivity type opposite to that of the base layer. The first conductivity type may be provided by a p-type layer, the second conductivity type may be provided an n-type layer, or vice versa. The heart of the solar cell is formed by the transition boundary between the emitter layer 11 and the base layer 12. Under the influence of light, photons and holes are created, which travel to opposite sides of the solar cell 1, i.e. the front and rear side 10, 20 of the solar cell 1.

To collect the charge from the front side 10 and the rear side 20, conducting elements 15, 24 may be provided on the front and rear side, to enable transportation of the charges. The conducting elements 15, 24 may be formed by a suitable conductive material, such as silver, aluminium, copper, conducting oxides like TiO_x or organics. The conducting elements 15, 24 may be formed in any suitable pattern.

Especially the pattern of conducting elements 15 on the front side 10 may be carefully designed as to provide optimal balance between a dense pattern for facilitating easy transportation of charges and a non-dense pattern as to minimize the shadow-effect of the conducting elements 15 on the solar cell 1.

Fig. 1a schematically shows an example of such a pattern. A further example of a possible pattern is described in "*The Starfire project: towards in-line mass production of thin high efficiency back-contacted multicrystalline silicon solar cells*" , by M.N. van den Donker, 23rd European Photovoltaic Solar Energy Conference, 1 – 5 September 2008, Valencia, Spain.

The pattern of conducting elements 24 provided at the rear side 20 may be formed in different ways. For instance, the pattern of conducting elements 24 provided at the rear side 20 may be provided as an integral conducting layer, covering most of the rear side 20 area, which may be referred to as a solar cell 1 with full rear metallization.

The patterns of conducting elements 15 positioned at the front side 10 may comprise collecting points 14, wherein the charge carriers may be collected.

A number of solar cells 1 may be used to form a solar panel. Fig. 1a shows a solar cell. The different solar cells 1 are electrically connected in series forming a so-called string. By using a connection strip (also referred to as tab), the pattern on the front side 10 may be connected to the pattern at the rear side 20 of an adjacent solar cell, by connecting the conducting elements 15 on the front side to the conducting elements on the rear side 20 of an adjacent solar cell 1.

In order to reduce shadowing effects at the front side 10, different types of solar cells are known in the state of the art in which the collecting points associated with the front side generated charge carriers are provided on the rear side. The solar cell comprises an electrical conducting path between the front side 10 and at least one collecting point provided on the rear side, providing an electrical connection between the front side 10 and the rear side 20 to guide the first charge carriers from the front side 10 to the at least one collecting point 14' provided at the rear side 20. Different variants of such solar cells are known, such as metal wrap through solar cells, metal wrap around solar cells and emitter wrap through solar cells.

An example of a metal wrap through solar cell is provided below with reference to Fig.'s 1b and 1c.

Fig. 1b schematically shows a cross sectional view of a metal wrap through solar cell 1 with full rear metallization, according to the state of the art.

In metal wrap through solar cells, the collecting points 14 of the front side 10 are guided to the rear side 20. A hole or via 30 is formed in the solar cell 1 from front side 10 to rear side 20, providing the electrical conducting path, allowing collecting points 14' to be formed on the rear side 20. The collecting points 14' are electrically connected with the pattern of conducting elements 15 on the front side 10 via the electrical conducting path provided by the via 30.

The via 30 may be formed in any suitable way, for instance using a laser to drill the via's.

As a result, there is no more need to have tabs on the front side 10 of the solar cell 1. The solar cells may be electrically connected to each other by using connection strips (tabs) provided on the rear side. The connecting strips may also be formed by conducting foils.

In between the conducting elements 15 on the front side 10 a passivating and anti reflection coating 19 may be provided, as is shown in Fig. 1b.

The via 30 may be filled with a conductive material 18, such as a metal paste or an alternative conducting material, forming an electrical conducting path from the front side 10 to the rear side 20. The metal may be sintered metal.

At the interior wall of the via 30 an interface layer 13 may be formed of emitter material, i.e. having a doping level which is comparable, lower or higher compared to the doping level of emitter layer 11. The interface layer 13 is indicated in Fig. 1b by the dotted line.

Fig. 1c schematically shows a cross sectional view of an alternative solar cell as known in the prior art, i.e. a metal wrap through solar cell 1 with dielectric (or other, for instance amorphous Si or Silicon Carbide (SiC_x)) passivation and open rear metallization. This solar cell 1 is similar to the solar cell 1 described above with reference to Fig. 1b, except for the fact that the rear side 20 is not fully metalized. Furthermore, in between the pattern of conducting elements 24 on the rear side 20 a rear surface dielectric passivation layer 21 is provided, that can also extend along the interior wall of the via 30. In fact, the rear surface dielectric passivation layer 21 may be formed by a stack of different layers. This can be for instance a SiO_x/SiN_x stack or an AlO_x/SiN_x stack.

Above, two types of metal wrap through solar cells 1 were described with reference to Fig.'s 1b – 1c. However, it will be understood that alternative solar cells 1 are known and conceivable, such as metal wrap around and emitter wrap through solar cells. Depending on the type of solar cell 1, for instance with full aluminium rear surface for p-type base material (an example of which is shown in Fig. 1b) or bifacial with a passivated (by dielectric layer) rear surface for both p- and n-type base material (an example of which is shown in Fig. 1c), the electrical conductive path from front side 10 to rear side 20 (e.g. conductive material 18 in the via 30) and the collecting points 14' at the rear side 20 are in contact with the emitter layer 11 and the interface layer 13 or are in contact with the dielectric passivation layer 21.

Inside the electrical conducting paths from front side 10 to rear side 20, the emitter current is conducted from the front side 10 to rear side 20, for instance via a metal paste . However, during use, part of the emitter current may leak to the base layer 12. This effect is called shunting, the term shunting used in this text as also referring to non-linear shunting. This effect decreases the efficiency and stability of the solar cell 1. The electrical shunts decrease the fill factor (FF) and thereby the efficiency (V_{oc}*J_{sc}*FF) of the solar cells.

The term fill factor is known to the skilled person. It provides a definition of the overall behaviour of a solar cell, i.e. the ratio of the maximum power point divided by the open circuit voltage (V_{oc}) and the short circuit current (I_{sc}): $FF = P_m/(V_{oc} \cdot I_{sc})$.

As a result of this problem, the fill factor of solar cells 1 comprising collecting points at the rear side to collect charge carriers associated with the front side is relatively low.

Besides metal wrap through solar cells, also other types of solar cells are known from the prior art, which suffer from electrical shunts. Examples of such other solar cells are so-called metal wrap around (MWA) solar cells and emitter wrap through (EWT) solar cells. In these solar cells, the emitter current is also transported to the rear side 20 using an electrical conducting path between the front side and the at least one collecting point provided on the rear side, introducing the risk of shunting.

In a metal wrap around solar cell, the electrical conducting path is provided along side edges of the solar cell. In an emitter wrap through solar cell the electrical conducting path is provided by emitter material and/or a metal, running through the base layer towards the rear side 20. In all these alternative solar cells, the electrical conducting path is in contact with the base layer and the emitter current may leak to the base layer, in other words, shunting may occur.

Solar cells 1 as described here are for instance described in

- P. C. de Jong et al., Conference proceedings 19th EPVSEC, Paris, France (2004)
- A. W. Weeber et al., Conference proceedings 21st EPVSEC, Dresden, Germany (2006)
- F. Clement et al., Conference proceedings 22nd EPVSEC, Milano, Italy (2007)
- A. Mewe et al., Conference proceedings 23rd EPVSEC, Valencia, Spain (2008).

SHORT DESCRIPTION

It is an object of the present invention to provide a solar cell and method of fabricating such a solar cell that provides an increased fill factor.

According to an aspect there is provided a solar cell as defined in claim 1.

By providing an insulation layer 40 more efficient solar cells 1 are provided. The insulation layer 40 decreases losses in efficiency caused by shunting solar cells 1. The risk of electrical shunts is reduced and the electrical conducting path will no longer form a limiting factor for the output of the solar cell 1.

Furthermore, the possibility is created to process different types of solar cells 1 such as: metal wrap through solar cells with shallow or selective emitter, metal wrap through solar cells with a rear dielectric passivating layer, or n-type metal wrap through solar cells.

The improved solar cells allow industrialization of specific, new types of solar cells that are not yet ready for industrialization as these solar cells were not yet sufficiently efficient. This may for instance apply to metal wrap through solar cells using selective emitters or rear surface passivation, or to metal wrap through solar cells where the p-n junction is isolated using a wet chemical etch removing the emitter on the rear side. In these cells the emitter inside the vias will be shallow or even absent.

According to an aspect there is provided a method of manufacturing a solar cell as defined in claim 13.

Further aspects of the invention are described in the dependent claims.

SHORT DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, but are not used to limit the scope of the invention, and in which:

Fig.'s 1a – c schematically depict solar cells according to the state of the art;

Fig.'s 2a – b schematically depict solar cells according to different embodiments;

Fig.'s 3 and 4 schematically depict solar cells according to further embodiments.

DETAILED DESCRIPTION

The embodiments described below show solar cells 1 of different types, such as metal wrap through solar cells, metal wrap around solar cells and emitter wrap through solar cells.

Fig.'s 2a and 2b depict embodiments of a metal wrap through solar cell, comprising an electrical conducting path between the front side 10 and the rear side 20, which is formed by a via 30 which is provided with an insulating layer 40 on the interface between conductive material 18 provided inside the via 30 and the silicon substrate forming the solar cell 1. In case the conductive material 18 is a metal paste, the insulating layer 40 may be formed by an annealing treatment forming an insulating metal oxide layer on the outside of the conductive material 18. The insulating layer 40 may also be formed in another way and may be formed of a different material, as will be described in more detail below.

In general, the solar cell 1 is formed of a layer of semi-conductive material, such as silicon, provided in between a front side 10 and a rear side 20 of the solar cell. The solar cell comprises an emitter layer 11 at the front side 10 and a base layer 12 at the rear side 20.

The front side 10 with the emitter layer 11 is in use directed to a light source, such as the sun or for instance a reflector, reflecting sun light. In use, first charge carriers will gather at the front side 10 and second charge carriers of an opposite type as the first charge carriers gather at the rear side 20.

An electrical conducting path may be provided to carry first charge carriers collected by the emitter layer 11 to the rear side 20 of the solar cell. The electrical conducting path may be provided by a via 30 provided through the emitter layer 11 and the base layer 12, wherein the via 30 is filled with a conductive material 18 providing an electrical connection between the front side 10 to the rear side 20 to guide the first charge carriers from the front side 10 to collecting points 14' provided at the rear side 20. This is a so-called metal wrap through solar cell which is described in more detail below with reference to Fig.'s 2a and 2b.

The electrical conducting path may electrically connect the conducting elements 15 on the front side 10 of the solar cell to collecting points 14' at the rear side 20 of the solar cell 1.

Alternative solar cells, like emitter wrap through solar cells and metal wrap around solar cells are shown in Fig.'s 3 and 4, in which same reference numbers are used to refer to similar elements.

Fig. 3 shows an emitter wrap through solar cell wherein the electrical conducting path is formed by emitter material. The electrical conducting path extends through the base layer 12 and is at least partially filled with emitter material. The other part may be filled with metal or the like, integrally formed with the collecting point 14'.

These types of solar cells 1 have an emitter layer 11 on the front side 10, but have no emitter metallization, i.e. no conducting elements 15 on the front side. A via 30 is formed through the base layer 12 formed as an extension of the emitter layer 11, thus formed by emitter material. The collecting point 14' to collect the first charge carriers is formed on the rear side 20 and is in contact with the emitter material extending through the base layer 12. The collecting point 14' may be made of a conducting material, like metal and may extend in to the via 30 to some extent, meeting the emitter material.

Fig. 4 shows a metal wrap around solar cell, wherein the electrical conducting path is formed by a conductive material provided along at least one side edge 17 of the solar cell. So, instead of having an electrical conducting path extending through the base material 12, the electrical conducting path is formed around the base layer 12. In the prior art, the electrical conducting path was in contact with the base layer 12 introducing the risk of shunting, i.e. leaking of emitter current to the base layer 12. Thus, as shown in Fig. 4, the insulating layer 40 is provided in between the electrical conducting path and the base layer 12 to provide insulation between the conductive material and the base layer 12.

According to the embodiments, shunting is prevented or at least reduced , by providing an insulating layer 40 at least along part of the electrical conducting path provided to transport first charge carriers collected at the front side 10 to collecting points 14' provided at the rear side 20. The insulation layer 40 provides insulation between the electrical conducting path and the base layer 12.

The insulating layer 40 may be formed of a dielectric material, such as silicon nitride. In general the term insulating layer 40 is used to refer to a material that resists the flow of electric current.

In general, the insulating layer 40 has a resistivity that is substantially higher than the surrounding materials, such as the material forming the electrical conducting path (e.g. the conductive material 18 provided inside the via 30), the emitter layer 11 and the base layer 12. The insulating layer 40 may have a resistivity that is at least a factor 10 or 100 higher than the surrounding materials.

The insulating layer 40 may for instance be made of SiO_2 having a resistivity in the range of $10^{14} - 10^{16}$ Ωm, Al_2O_3 having a resistivity of approximately 10^{11}Ωm, Si_3N_4 having a resistivity of approximately 10^{14} Ωm, ZrO_2 having a resistivity of approximately 10^{10} Ωm. The insulating layer may also be made of Bi_2O_3.

The deposition (or other for instance oxidation) techniques used will not form perfect crystal structures. The deposition or oxidation techniques may also result in amorphous material. So, more generally for instance SiOx, AlOx, SiNx layers may be formed of which the resistivity may vary and may be lower than the values indicated in the paragraph above. In general, the insulating layer may formed of a material having a resistivity > 10^5 Ωm.

The insulating layer 40 may have any suitable thickness. A typical thickness may be in the range of 1 – 10 nm.

The embodiments presented here may be applied to all types of solar cells 1, having an electrical conductive path to transport first charge carriers to collecting points 14' at the rear side 20, for instance with a full aluminium rear surface or with a rear side passivating coating. Also, the embodiments may be applied to solar cells of which the base material, i.e. the base layer 12 is made of either p-type or n-type base material.

Now, two embodiments will be described in more detail with reference to Fig.'s 2a and 2b.

Fig.'s 2a and 2b schematically depict embodiments corresponding to the state of the art examples described above with reference to Fig.'s 1b and 1c respectively.

Fig. 2a schematically depicts a metal wrap through solar cell 1 with full aluminium rear surface. This type of solar cell 1 is discussed in more detail above with reference to Fig. 1b. In this embodiment, an insulating layer 40 is formed. As shown, the insulating layer 40 is formed from the conductive material 18 forming the electrical conducting path between the front side 10 and collecting points 14' at the rear side. Interface layer 13 may still be present, but may also be absent, depending on the manufacturing process used.

As will be described in more detail below, the insulating layer 40 may be formed from the conductive material 18, for instance in case the conductive material is a metal, the insulating layer 40 may be formed by performing a high temperature annealing action as part of the manufacturing method.

Fig. 2b schematically depicts a metal wrap through solar cell 1, which is bifacial with a passivated (by dielectric layer) rear surface and a pattern of conducting elements 24. Similar as to Fig. 2a, an insulating layer 40 is formed.

The insulating layer 40 may be formed in any suitable way. This applies to all types of solar cells having an electrical conducting path to carry first charge carriers collected at the front side (i.e. formed in the emitter layer) to collecting points 14' at the rear side 20.

The insulating layer 40 may for instance consist of an oxide layer. The oxide layer may be formed in the manufacturing process as will be explained in more detail below. Providing an oxide layer is an efficient way of providing an insulating layer 40, which can be obtained by performing an oxidation action in which one of the materials already present is oxidized to form an insulating layer. As a result, no additional material is required.

The insulating layer 40 may be formed by a metal oxide layer. The metal oxide layer may be formed by performing an oxidizing action, such as a high temperature annealing action causing the metal conductive material 18 provided in the via 30 to oxidize on the outside. Examples of metal oxides that may be used are ZrO_2, PbO_x and Bi_2O_3. Examples of this are provided in Fig.'s 2a and 2b. The metal oxide layer may be an aluminium-oxide layer.

The insulating layer 40 may be a dielectric layer. The insulating layer 40 may alternatively be formed by one of a silicon oxide layer and a silicon-nitride layer. In these cases, the oxide layer is not formed from the conductive material, but is formed from the silicon material forming the emitter layer 11 and the base layer 12. The insulating layer can also be any other dielectric layer like silicon carbide.

The silicon oxide layer may be formed by performing an oxidizing action causing the silicon material facing the electrical conductive path to oxidize and thereby forming an insulating layer 40. This may be the material facing the inside of the via 30 or the material forming the side edge 17 of the solar cell.

The oxidizing action may comprise a wet chemical oxidizing action or may comprise a thermal oxidizing action. Alternatively, the oxidizing action may comprise deposition of a SiO_x-layer, for instance by means of PECVD (plasma enhanced chemical vapour deposition).

According to an embodiment the insulation layer 40 is provided to prevent direct physical and electrical contact between the electrical conducting path, i.e. the conductive material 18 inside the via 30, and the base layer 12. The insulation layer 40 may cover the complete outside of the conductive material 18 that faces the base layer 12 along the entire inner surface of the via 30.

The electrical conducting path may be formed as an elongated part extending through the emitter layer 11 and the base layer 12 towards a collecting point 14' provided on the rear side 20. The collecting point 14' may have a contacting area 141 facing away from the solar cell 1 and a rear area 142 facing the base layer 12. The insulation layer 40 may be provided along the elongated part of the electrical conducting path . The insulation layer 40 may also be provided on the rear area 142 of the collecting point 14', i.e. between the rear area 142 and the base layer, to prevent direct physical contact between the collecting point 14' and the base layer 12, thereby reducing shunts between the collecting point 14' and the base layer 12. Thus, the insulating layer 40 may also extend to the rear side of the solar cell.

The collecting point 14' may have dimensions in a direction parallel to the front and rear side 10, 20 that are substantially larger than the dimension of the electrical conducting path extending through the base layer 12, e.g. inside the via 30, in that same direction. The collecting point 14’ may be used to be electrically connected to a connection strip or tab.

The elongated part of the electrical conducting path, e.g. the conductive material 18 inside the via, and the collecting point 14’ may be formed as one piece, but may also be formed as two elements.

In the embodiments depicted in Fig.’s 2a and 2b, the insulating layer 40 extends along the entire length of the via 30, i.e. is also present in the emitter layer 11. It will be understood that shunting will only occur with respect to the base layer 12, so embodiments may be provided in which the insulating layer 40 is only present between the conductive material 18 and the base layer 12. This can be both inside the via 30, and on the rear area 142 of the collecting point 14’.

However, as will become clear from the explanation of the embodiments for manufacturing solar cells as presented here, for at least some methods of manufacturing, the insulation layer 40 will inherently also be present inside the emitter layer.

The solar cells 1 according to the embodiments provided above may be used to form a solar panel, the solar panel comprising two or more of such solar cells 1.

Method of manufacturing

According to a further embodiment there is provided a method of manufacturing a solar cell 1 comprising an insulating layer 40 as described above.

A method of manufacturing a solar cell may comprise one or more of the following actions:

- providing a semiconductor substrate, the semiconductor substrate having a front side 10 and a rear side 20,

- applying a surface roughening (texturing) on the front side 10 to increase the light entrapment,

- forming an emitter layer 11 on the front side 10 of the semiconductor substrate with a conductivity of a first type and a base layer 12 having a conductivity of the second type, opposite to the conductivity of the first type,

- forming collecting points 14’ at the rear side,

- forming an electrical conducting path between the front side 10 and the collecting points 14’ at the rear side 20.

For a metal wrap through solar cell the method may comprise:

- forming at least one via 30 from the front side 10 to the back side 20 through the semiconductor substrate to form the electrical conducting path,

- providing a conductive material 18 inside the via 30.

For an emitter wrap through solar cell the method may comprise:

- forming at least one via 30 from the front side 10 to the back side 20 through the semiconductor substrate, at least the base layer 12, to form the electrical conducting path, the via comprising emitter material and possible metal material.

For a metal wrap around solar cell the method may comprise:

- forming the electrical conducting path around a side edge 17 of the semiconductor substrate to form the electrical conducting path, the via comprising emitter material.

The method further comprises

- forming an insulating layer 40 at least along part of the electrical conducting path to provide insulation between the electrical conductive path and the base layer 12.

It is emphasized that the order of these actions may be different as mentioned here, as will be understood by a skilled person.

The formation of the emitter layer 11 and the base layer 12 may be done in any suitable way, as will be understood by the skilled person. For instance, the emitter layer may be formed on the semiconductor substrate by providing a diffusion source layer on the front side 10 of the semiconductor substrate and subsequently performing a diffusion action forming the emitter.

The base layer may be of the p-type or of the n-type, the emitter being of the opposite type.

According to an embodiment forming of an insulating layer 40 may comprise performing an oxidation action. The oxidation action may be a (high temperature) annealing action.

According to an embodiment, the oxidation action may be applied to the electrical conducting path, e.g. the conductive material 18. So, in case the conductive material is formed by a metal, the oxidation action may be performed by oxidizing the outer layers of the electrical conducting path, e.g. the conductive material 18 after it has been provided inside the via 30, thereby forming a metal oxide layer . Examples of metal oxides are ZrO_2 en Bi_2O_3.

According to an alternative embodiment the oxidation action may be applied to the semiconductor substrate facing the electrical conducting path, e.g. facing the walls of the via 30 or forming side edges 17. By doing this, a oxide layer may be formed , for instance a silicon oxide layer. This may be done before adding the electrical conducting path, e.g. before adding conductive material 18 (e.g. metal paste).

In general, the oxidation action of the semiconductor substrate may comprise a wet chemical oxidizing action or may comprise a thermal oxidizing action.

According to a further embodiment forming an insulating layer 40 may comprise deposition of an insulating layer 40, such as deposition of a SiO_x-layer, for instance by means of PECVD (plasma enhanced chemical vapour deposition), atomic layer deposition (ALD) or sputtering. The insulating layer 40 may be deposited on the parts of the semiconductor substrate facing the electrical conducting path, e.g. facing the walls of the via 30 or forming side edges 17. In case a via 30 is formed, this may be done after the via 30 has been formed, before the electrical conducting path is provided, e.g. before conductive material 18 is provided. Alternatively, the insulating layer 40 may be a silicon nitride layer, or an aluminium-oxide layer.

The method may further comprise further processing the semiconductor substrate to a solar cell. These further actions will be known to a person skilled in the art. The further processing actions may comprise:

- providing the anti reflective and passivating coating(s) 19 on the front side 10,
- providing the passivating coating(s) 21 on the rear side 20,
- in case of a metal wrap through solar cell or a metal wrap around solar cell, providing conducting electrodes 15 on the front side 10,
- providing conducting elements on the rear side 20,
- applying an annealing step to form electrical contact from the electrodes to the emitter and base material,
- if necessary provide a p-n-junction isolation.

The descriptions above are intended to be illustrative, not limiting. Thus, it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from its scope as defined by the claims set out below, and their technical equivalences.

CONCLUSIES

1. Zonnecel (1), omvattende een voorzijde (10) en een achterzijde (20), waarbij de zonnecel (1) een emitter-laag (11) omvat aan de voorzijde (10) en een base-laag (12) aan de achterzijde (20), waarbij de voorzijde is ingericht voor het ontvangen van licht ten gevolge waarvan eerste ladingsdragers zich verzamelen aan de voorzijde (10) en tweede ladingsdragers van een tegengesteld type als de eerste ladingsdragers zich verzamelen aan de achterzijde (20),
waarbij de zonnecel (1) verder ten minste een verzamelpunt (14’) omvat welke verschaft is aan de achterzijde (20) en een corresponderend elektrisch geleidend pad tussen de voorzijde (1) en het ten minste ene verzamelpunt (14’), welke een elektrisch geleidend pad verschaft tussen de voorzijde (10) en de achterzijde (20) om eerste ladingsdragers te geleiden van de voorzijde (10) naar het ten minste ene verzamelpunt (14’) verschaft aan de achterzijde (20),
met het kenmerk dat een isolatielaag (40) verschaft is tussen ten minste een deel van het elektrisch geleidende pad en de base-laag (12) om elektrische isolatie te verschaffen tussen het elektrisch geleidende pad en de base-laag (12).

2. Zonnecel volgens conclusies 1, waarbij het elektrisch geleidende pad gevormd is door een via (30) welke zich ten minste uitstrekt door de base-laag (12), en de isolatielaag (40) verschaft is ten minste rondom een gedeelte van de via (30) ten einde isolatie te verschaffen tussen de via (30) en de base-laag (12).

3. Zonnecel volgens conclusie 2, waarbij de via (30) is gevuld met een geleidend materiaal (18).

4. Zonnecel volgens conclusie 2, waarbij de emitter-laag gevormd wordt door emitter-materiaal en de via (30) ten minste gedeeltelijk gevuld is met emitter-materiaal.

5. Zonnecel volgens conclusie 1, waarbij het elektrisch geleidende pad gevormd wordt door een geleidend materiaal dat verschaft is langs zijranden (17) van de zonnecel, waarbij de isolatielaag (40) verschaft is tussen het elektrisch geleidende pad

en de base-laag (12) ten einde isolatie te verschaffen tussen het geleidend materiaal en de base-laag (12).

6. Zonnecel (1) volgens een van de voorgaande conclusies, waarbij de zonnecel (1) een is van een zonnecel met volledig metalen achterzijde en een tweezijdige zonnecel met een gepassiveerde achterzijde en een patroon van geleidende elementen (24) aan de achterzijde.

7. Zonnecel volgens een van de voorgaande conclusies, waarbij de isolatielaag (40) een oxidelaag is.

8. Zonnecel volgens conclusie 7, waarbij de isolatielaag (40) een metaaloxidelaag is.

9. Zonnecel volgens conclusie 7, waarbij de isolatielaag (40) een diëlektrische laag is, zoals een silicium-oxidelaag of een silicium-nitridelaag.

10. Zonnecel volgens een van de voorgaande conclusies, waarbij de isolatielaag (40) verschaft is voor het voorkomen van direct elektrisch contact tussen het geleidend materiaal (18) en de base-laag (12).

11. Zonnecel (1) volgens een van de voorgaande conclusies, waarbij het ten minste ene verzamelpunt (14') een contactgebied (141) omvat dat van de zonnecel (1) af gekeerd is en een achtergebied (142) dat naar de base-laag (12) toe gekeerd is, waarbij de isolatielaag (40) ook verschaft is tussen het achtergebied (142) van het verzamelpunt (14') en de base-laag (12).

12. Zonnepaneel, omvattende twee of meer zonnecellen volgens een van de voorgaande conclusies.

13. Werkwijze voor het vervaardigen van een zonnecel, waarbij de werkwijze omvat:
- het verschaffen van een halfgeleider substraat welke een voorzijde (10) en een achterzijde (20) omvat,

- het vormen van een emitter-laag (11) aan de voorzijde (10) van het halfgeleider substraat,
- het vormen van ten minste een elektrisch geleidend pad van de voorzijde (10) naar een corresponderend verzamelpunt (14') aan de achterzijde (20),

gekenmerkt doordat de werkwijze verder omvat
- het vormen van een isolatielaag (40) ten einde isolatie te verschaffen tussen het elektrisch geleidende pad en de base-laag (12).

14. Werkwijze volgens conclusie 13, waarbij het elektrische geleidende pad een via (30) is, welke zich ten minste uitstrekt door de base-laag (12), en het vormen van de isolatielaag (40) omvat het vormen van de isolatielaag (40) ten minste rondom een gedeelte van de via (30) ten einde isolatie te verschaffen tussen de via (30) en de base-laag (12).

15. Werkwijze volgens conclusie 14, waarbij het vormen van het ten minste ene elektrische geleidende pad omvat het vormen van het ten minste ene elektrische pad van een geleidend materiaal of emitter-materiaal.

16. Werkwijze volgens conclusie 13, waarbij het vormen van het ten minste ene elektrische geleidend pad omvat het vormen van het ten minste ene elektrische pad lang een zijrand (17) van de zonnecel, waarbij de isolatielaag (40) is verschaft tussen het elektrische geleidend pad en de base-laag (12) ten einde isolatie te verschaffen tussen het geleidende materiaal en de base-laag (12).

17. Werkwijze volgens een van de conclusies 9 – 16, waarbij het vormen van de isolatielaag (40) omvat het uitvoeren van een oxidatiestap.

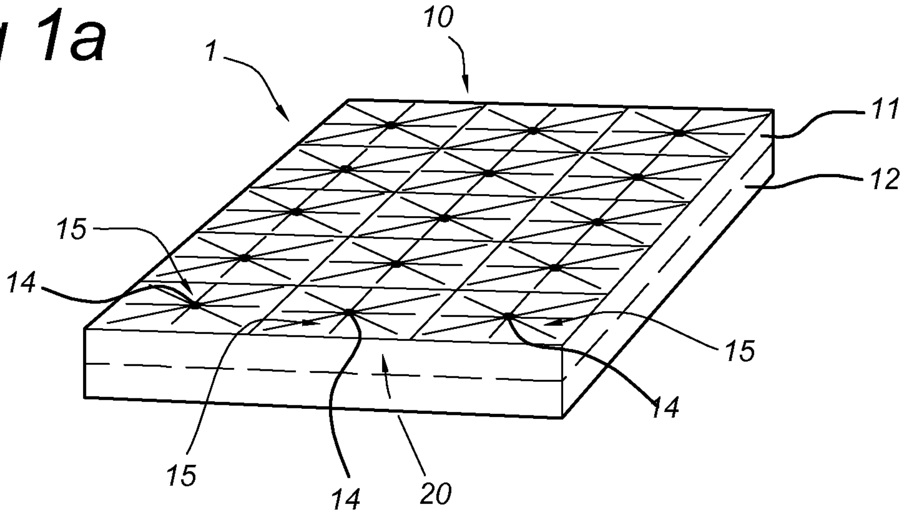
18. Werkwijze volgens conclusie 17, waarbij de oxidatiestap wordt uitgevoerd door een warmtebehandelingsstap.

19. Werkwijze volgens conclusie 17, waarbij de oxidatiestap wordt toegepast op het elektrisch geleidende pad.

20. Werkwijze volgens conclusie 17, waarbij de oxidatiestap wordt toegepast op delen van het halfgeleidersubstraat die naar het elektrische geleidende pad zijn toegekeerd.

21. Werkwijze volgens een van de conclusies 9 – 16, waarbij het vormen van de isolatielaag (40) wordt uitgevoerd door depositie van de isolatielaag (40).

Fig 1a


1
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11
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14
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14
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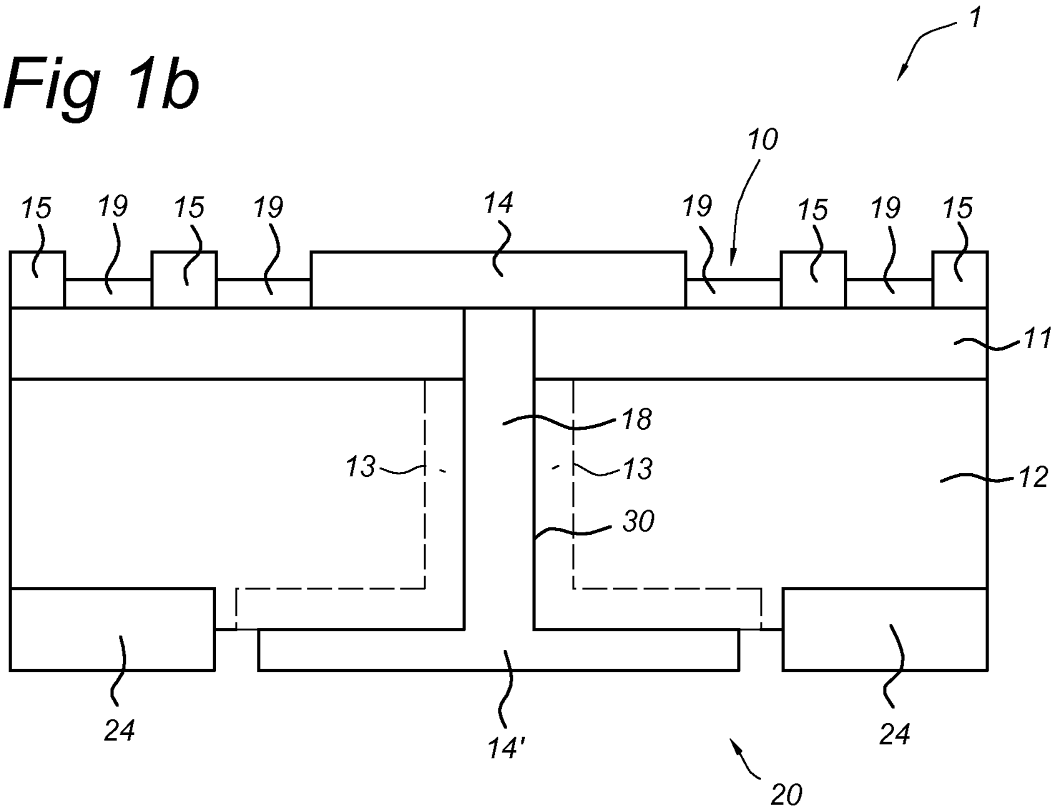
14
20

Fig 1b


1
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12
30
24
14'
24
20

Fig 1c

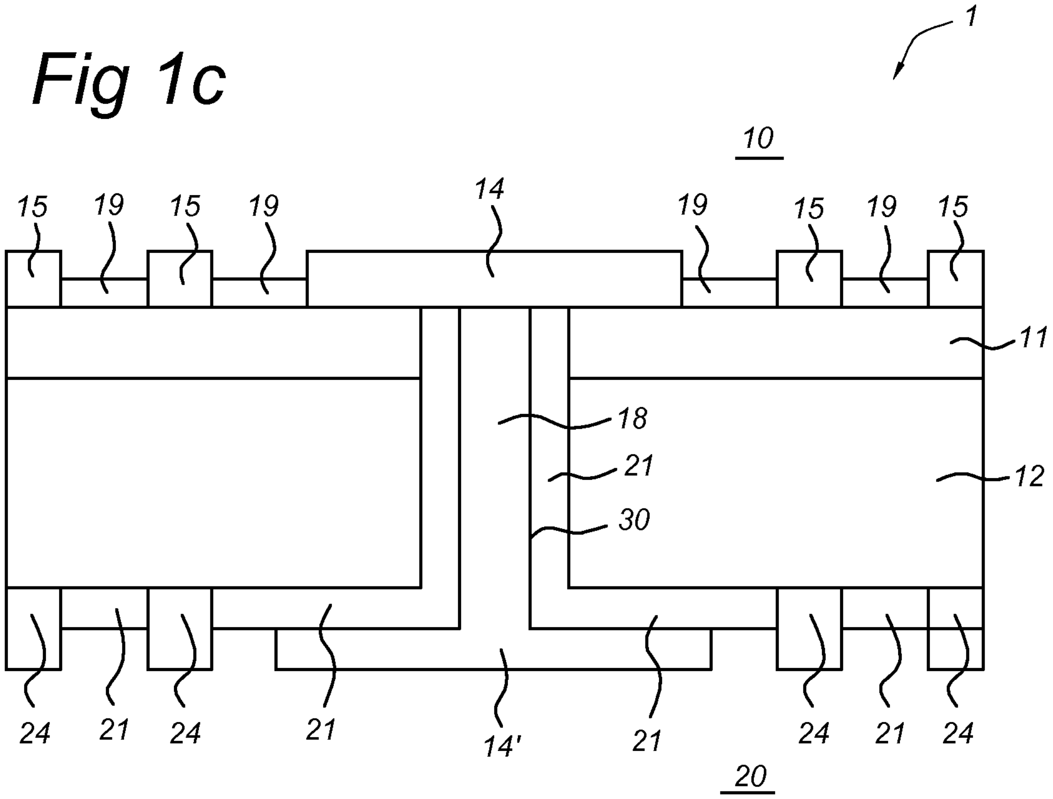
1
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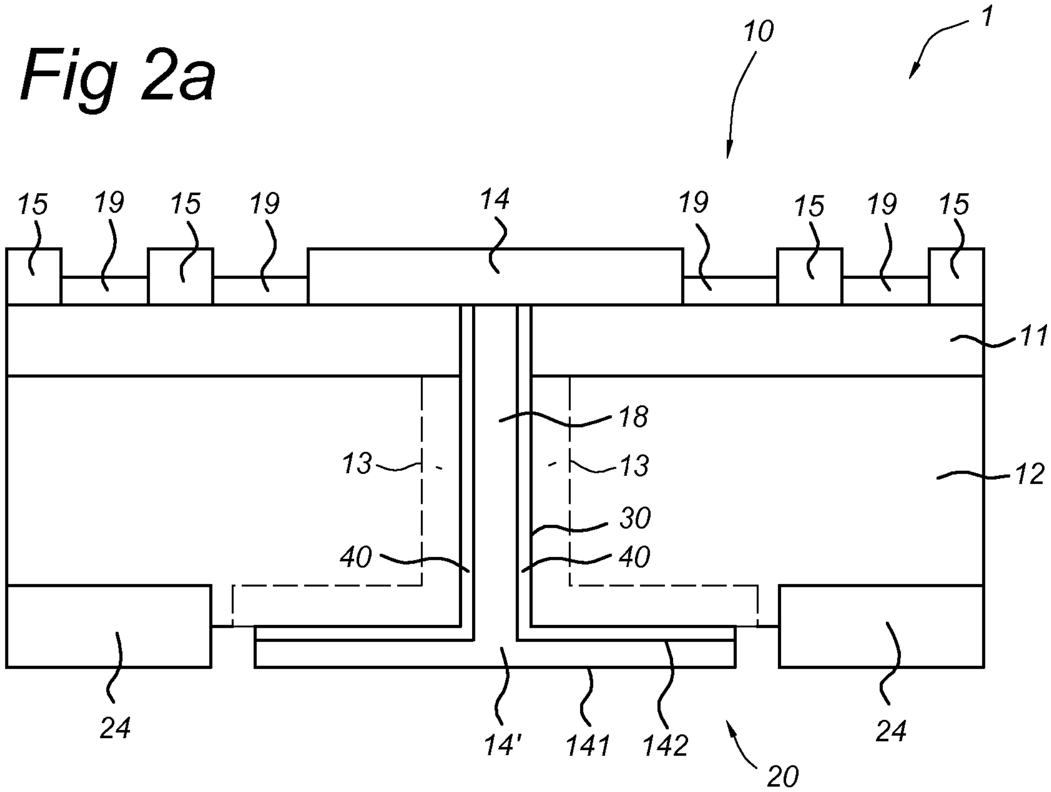
Fig 2a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40
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14'
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142
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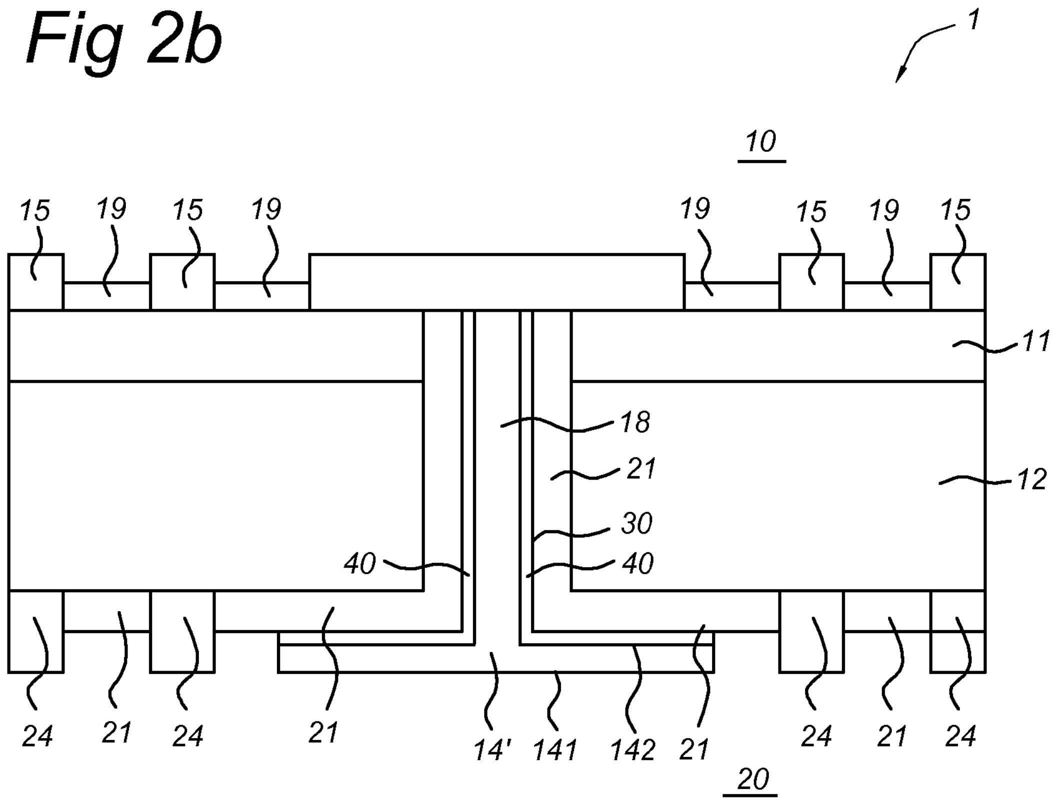
Fig 2b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12
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14'
141
142
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24
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24
20

Fig 3

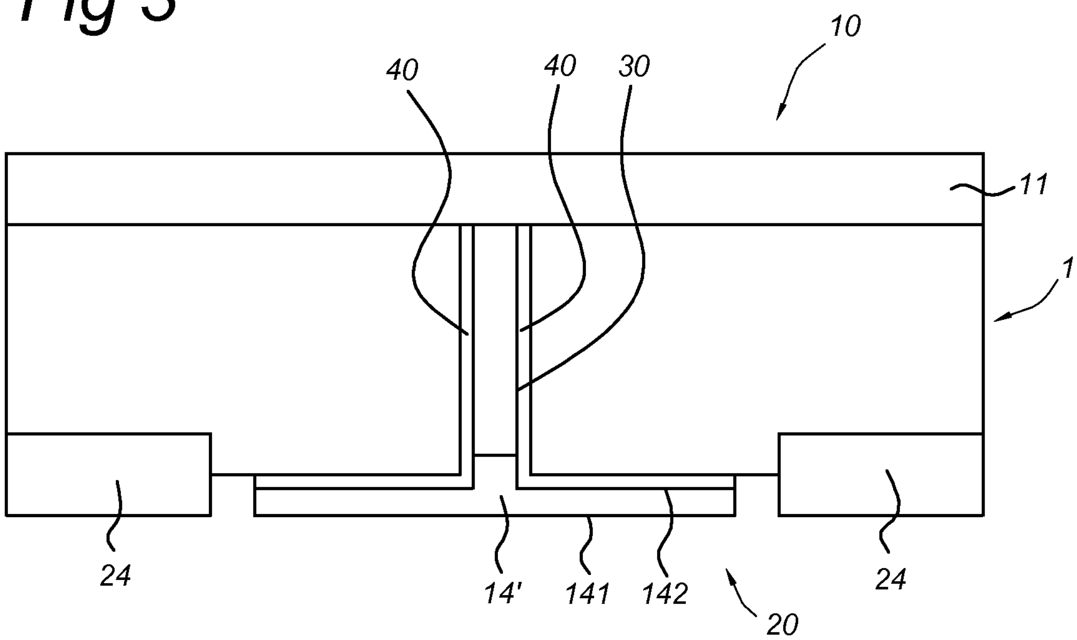
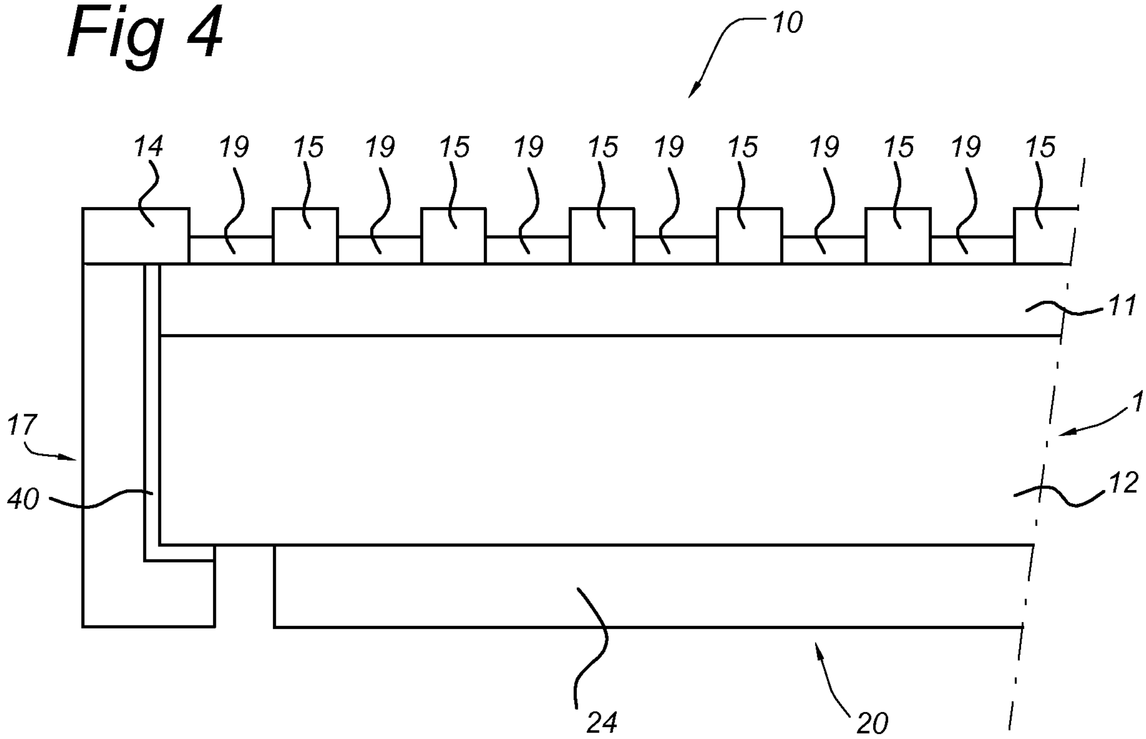

10
40
40
30
11
1
24
14'
141
142
24
20

Fig 4



SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	**KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE** **P6029961NL**
Nederlands aanvraag nr. **2004698**	Indieningsdatum **11-05-2010**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Stichting Energieonderzoek Centrum Nederland**	
Datum van het verzoek voor een onderzoek van internationaal type **31-07-2010**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN 54609**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

H01L31/0224

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC8	**H01L**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	☐	**GEBREK AAN EENHEID**	(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2004698

A. CLASSIFICATIE VAN HET ONDERWERP
INV. H01L31/0224
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
H01L

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data, INSPEC

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 3 903 427 A (PACK GEORGE J) 2 september 1975 (1975-09-02) * kolom 1, regel 30 - kolom 2, regel 47; conclusie 1; figuren 1,2 *	1-3,10, 11,13-15
X	EP 2 068 369 A1 (IMEC INTER UNI MICRO ELECTR [BE]; PHOTOVOLTECH [BE]) 10 juni 2009 (2009-06-10) * alinea [0009] - alinea [0014] * * alinea [0031] - alinea [0058]; conclusies; figuren *	1-4, 6-15,17, 21
X	EP 0 528 311 A2 (SPECTROLAB INC [US]) 24 februari 1993 (1993-02-24) * kolom 4 - kolom 8; conclusies; figuren 5a-5c *	1-3,10, 13-15

-/--

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

10 december 2010

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie
European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Bakker, Jeroen

1

Formulier PCT/ISA/201 (tweede blad) (Januari 2004)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2004698

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 2003/022475 A1 (VIEUX-ROCHAZ LINE [FR] ET AL) 30 januari 2003 (2003-01-30) * alinea [0002] - alinea [0006]; figuren 1a-1c * -----	13,17, 18,20
X	EP 1 703 553 A2 (SHARP KK [JP]) 20 september 2006 (2006-09-20) * alinea [0003] - alinea [0017] * * alinea [0029] - alinea [0031] * -----	13,17, 19,20
X	WO 89/05521 A1 (SPECTROLAB INC [US]) 15 juni 1989 (1989-06-15) * bladzijde 5 - bladzijde 6; figuren 1,2,4 * -----	1-3,10, 13-15
X A	US 2008/009087 A1 (WADA KENJI [JP]) 10 januari 2008 (2008-01-10) * alinea [0092]; figuur 7D * * alinea [0069] - alinea [0118]; figuren 6,7 * -----	1-3,10, 13-15,21 20
X	US 4 610 077 A (MINAHAN JOSEPH A [US] ET AL) 9 september 1986 (1986-09-09) * kolom 3 - kolom 6; conclusies; figuren 1a-1j * -----	1-3,5,7, 9,13-16, 21
X	US 6 156 967 A (RALPH EUGENE [US] ET AL) 5 december 2000 (2000-12-05) * kolom 4; figuur 1c * -----	1,5,7

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2004698

In het rapport genoemd octrooigeschrift		Datum van publicatie	Overeenkomend(e) geschrift(en)			Datum van publicatie
US 3903427	A	02-09-1975	GEEN			
EP 2068369	A1	10-06-2009	CN	101889349	A	17-11-2010
			EP	2215663	A2	11-08-2010
			WO	2009071561	A2	11-06-2009
EP 0528311	A2	24-02-1993	AU	648921	B2	05-05-1994
			AU	2090792	A	25-02-1993
			DE	69216502	D1	20-02-1997
			DE	69216502	T2	24-04-1997
			ES	2095991	T3	01-03-1997
			JP	5326991	A	10-12-1993
			US	5425816	A	20-06-1995
US 2003022475	A1	30-01-2003	EP	1259983	A1	27-11-2002
			FR	2805709	A1	31-08-2001
			WO	0165598	A1	07-09-2001
			JP	2003526207	T	02-09-2003
EP 1703553	A2	20-09-2006	JP	4199206	B2	17-12-2008
			JP	2006261553	A	28-09-2006
			US	2006211269	A1	21-09-2006
WO 8905521	A1	15-06-1989	GEEN			
US 2008009087	A1	10-01-2008	US	2009221108	A1	03-09-2009
US 4610077	A	09-09-1986	DE	3572088	D1	07-09-1989
			EP	0179860	A1	07-05-1986
			JP	61502017	T	11-09-1986
			WO	8505225	A1	21-11-1985
US 6156967	A	05-12-2000	US	6407327	B1	18-06-2002

OCTROOICENTRUM NEDERLAND

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN54609	11.05.2010		NL2004698

International Patent Classification (IPC) INV. H01L31/0224
Applicant Stichting Energieonderzoek Centrum Nederland

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the application
- ☐ Box No. VIII Certain observations on the application

	Examiner
	Bakker, Jeroen

Application number
NL2004698

WRITTEN OPINION

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	18-20
	No:	Claims	1-17, 21
Inventive step	Yes:	Claims	
	No:	Claims	1-21
Industrial applicability	Yes:	Claims	1-21
	No:	Claims	

2. Citations and explanations

see separate sheet

The following documents are refered to:

D1	US 3 903 427 A (PACK GEORGE J) 2 september 1975 (1975-09-02)
D2	EP 2 068 369 A1 (IMEC INTER UNI MICRO ELECTR [BE]; PHOTOVOLTECH [BE]) 10 juni 2009 (2009-06-10)
D3	EP 0 528 311 A2 (SPECTROLAB INC [US]) 24 februari 1993 (1993-02-24)
D4	US 2003/022475 A1 (VIEUX-ROCHAZ LINE [FR] ET AL) 30 januari 2003 (2003-01-30)
D5	EP 1 703 553 A2 (SHARP KK [JP]) 20 september 2006 (2006-09-20)

1. Metal wrap through solar cells (claims 1 to 3)

Metal wrap through solar cells with an isolated via have been known since 1975, see document D1 (claim 1, figures & corresponding text), which is novelty destroying for the subject-matter of claims 1 to 3.

In detail, the recent document D2 discloses:

a solar cell (paragraph [0001],[0023]-[0024] figure 3), comprising a front side and a rear side,

wherein the solar cell comprises an emitter layer (20) at the front side (column 5, line 3) and a base layer (29) at the rear side, wherein the front side is arragned to recieve light as a result of which first charge carriers collect at the front side and second charge carriers of an opposite type as the first charge carriers collect at the rear side,

wherein the solar cell further comprises at least one collecting point (33) provided at the rear side (figure 3) and a corresponding electrical conducting path between the front side and the at least one collecting point, providing an electrical connection between the front side and the rear side to guide the first charge carriers from the front side to the at least one collecting point (33) provided at the rear side (column 5, lines 36-53) wherein an insulating layer is provided between at least part of the electrical conducting path and the base layer to provide electrical insulation between the electrical conductive path and the base layer (abstract; paragraph [0024], figure 3), wherein the conducting path is formed by a via (25) (same references), and wherein the via is filled with a conductive material (23,33) (paragraph [0023], last lines; paragraph [0024]).

The subject-matter of claims 1-3 is therefore not new.

The corresponding method according to claims 13-15 comprise furthermore steps of forming an emitter layer (D2: paragraph [0023]), forming a conductive path (paragraph [0024]) and forming an insulating layer (paragraphs [0023],[0033],[0034]) is consequently known as well.

2. Metal wrap around solar cells (claims 1 and 5)

Document D3 discloses a metal wrap around solar cell with isolation (12), see figures 1a-1j, in particular figure 1j, and corresponding text in columns 3-6 and claims. It also shows an isolated (12) via (17) which contains a conductive path provided by metallisation (36).

Therefore, document D3 renders the subject-matter of claims 1-3, 5, 13-16 not new.

3. Emitter wrap through solar cells (claims 1, 2 and 4)

The need for isolation of sidewalls of emitter wrap through solar cells is the same as for metal wrap through solar cells. Therefore it would be obvious to the skilled person to consider solutions in terms of isolation material, such as disclosed in D2 or D1, to solar cells where the holes are filled with emitter material instead of metal, thus arriving at the subject-matter of claim 4 without exercising an inventive step.

4. Solar panel according to claim 12

The principle of applying individual solar cells in a solar panel is widespread. Therefore, the skilled person would consider to apply the solar cell with isolated vias disclosed in D2 in a solar panel, thus rendering the subject-matter of claim 12 not inventive.

5. The details in the subclaims are known or do not seem to bring inventive step.

The subject-matter of the following claims is known as well:

- claim 6: D2 discloses a solar cell with a passivated rear surface (figures 1,2, paragraphs [0055]-[0057]). Paragraphs [0031] and [0044] of D2 anticipate the application as a bificial solar cell. The adaptations of the back metal layer that are necessary are also anticipated by paragraph [0044] of D2. In the light thereof, the application of a pattern of conducting elements at the rear surface would be obvious to the skilled person.

- claim 7: see D2, abstract, paragraph [0033]

- claim 8: see D2: paragraph [0034]

- claim 9: see D2: paragraph [0033]

- claim 10 is an implication of practically all disclosures that have the features of claims 1 and 2, for instance D1 (figures); D2 (figures).

- claim 11: see D2 (figures 3, 4 and paragraphs [0023],[0024], [0025])

- claim 17: see D2 (paragraph [0033]), pyrolithic oxide implies an oxidation action.

-claim 21: see D2: paragraph [0033], last lines, paragraph [0058]: column 13, lines 8-19.

6. The subject-matter of the following claims lacks an inventive step:

- With respect to claim 18 document D4 (US2003022475) is considered to represent the closest prior art. It discloses thermal oxidation of through holes in a semiconductor substrate (paragraphs [0004]-[0006], figures 1a-1c), applied to semiconductor applications in the broadest sense, including sensors (paragraph [0002]). Sensors include light sensors, which are similar to solar cells. D4 does not explicitly disclose application to solar cells. However, it applies to semiconductor devices with through holes. Therefore, the skilled person would consider that thermal oxidation of through holes is demonstrated to work for semiconductor devices in general. Consequently it would have potential to apply oxidation to through holes in metal wrap through solar cells, and arrive at the subject-matter of claims 13, 17,18 and 20 without exercising an inventive step.

- with respect to claim 19 document D5 (EP1703553) is considered to represent the closest prior art. It discloses an oxidation action applied to the electrical conducting path in a through hole of a semiconductor substrate, thus forming an insulating layer (third embodiments, paragraphs [0029]-[0031]). D5 applies to semiconductor devices in general, and does not explicitly disclose application in solar cells. The skilled person would however consider that the teachings of D5 provide a proof of the concept of oxidising conductive material in a through hole and providing isolated sidewalls. Considering that the substrate material (silicon, see paragraph [0020]) and the needs (providing isolated through contacts; paragraphs [0003],[0015]) are the same, it would not involve an inventive step to apply the general concept to a specific through hole semiconductor application such as a metal wrap through solar cells. The formation of an emitter layer would be obvious in that respect. Hence, the subject-matter of claims 13, 17, 19 and 20 is not considered to involve an inventive step.