and requires to realize a passivation of the trenches in order to maintain a high efficiency. A subsequent metallization step has to be performed of the active semiconductor and the metal layer has subsequently to be patterned and isolated between the P and N regions. Chemical etching is preferably used to pattern the metal layer and the patterning of the Si layer. The sequence of Si trench formation, masking, etching, contact opening, metal isolation to form an IBC cell is a tedious and complex process.

Another document US 2019/237608A1 describes a process to realize an IBC solar cell. The process described in US 2019/237608A1 is complex, with 4 to 6 different etching steps. Each etching step implying the deposition of a patterned resist layer, the etching process of the non-protected layers and the removing, for example by stripping, of the resist. The multiple steps therefore considerably increase the solar cell cost because of a higher operational cost and a reduction in the production yield and would not allow to provide cheap and efficient IBC devices.

There is thus a need for a more simplified process to realize conducting contact structures that should be less expensive while at the same time assuring high reliability and possibly improved efficiency.

Summary of the invention

The present invention relates to a photovoltaic device which allows to alleviate the disadvantages of the prior art. In particular the claimed invention allows to provide a considerable simplification of the back-end process flow of an IBC solar cell by using a conductive layer together with the use of conducting compound or paste contacts, where the patterned and interdigitated conducting contact structure is realized by the deposition of only one resin masking layer including apertures of at least two different types, a localized deposition of contact pads and one etch process. In particular, the multiple function of the resin layer, which remains permanently onto the solar cell, allows a strong simplification of the back-end process flow.

~~In a first aspect, the invention is achieved by~~ According to a first aspect of the present invention, there is provided a method for manufacturing an interdigitated back contact (IBC) photovoltaic device comprising a substrate defining a

plane (X-Y) and, parallel to said plane (X-Y), a longitudinal (A-A) and a lateral (B-B) direction, orthogonal to said ~~lateral~~ longitudinal direction (A-A) and comprising the steps (A-E) of:

Step A: providing a substrate of a first- or second type doping being an n-type or a p-type doping and having a front side and a back side and realizing on said back side a semiconducting structure defining a front surface to the side of said substrate and a back surface opposite to said front surface, the semiconducting structure comprising individual doped portions of said first type doping and a doped semiconducting structure of a second type, being of the other type than said first type, to provide alternating electrical charge-types of semiconducting contacts.

Step B: realizing a conductive layer on top of doped semiconducting structures

Step C: realizing a patterned isolation resist layer, having a back surface, onto said conductive layer, and so that the formed resist layer comprises resist parts and ~~resist~~ contact apertures~~,~~ and isolation apertures, and so that the patterns of the isolation resist layer are aligned relative to said semiconducting structures;

Step D: applying a plurality of conductive pads onto said isolation resist layer, and so that the conductive pads fill said ~~resist~~ contact apertures making electrical contact to said conductive layer. Additionally, the conductive pads, by filling said resist apertures, protect the underlying conductive layer against chemical attack in the following etching step.

Step E: etching of the conductive layer in areas specified by isolation apertures in the isolation resist layer and realize trenches, extending between said back surface to at most the back surface of said semiconducting structure, to form electrically separated first type charge collecting structures F1 ~~from~~ and second type charge collecting structures F2. By ~~that~~ the trenches electrical separating the conductive layer and the plurality of conductive pads, first type charge collecting structures F1 and second type charge collecting structures F2 are formed~~.~~, the trenches extending between said back surface to at most the back surface of said semiconducting structure.

Conductive pads realized by Step D can also jut out of the resist apertures and facilitate, by jutting out above the surface and/or jutting out of the apertures in X and/or Y direction of the resist, contacting to ribbons or wires for interconnecting individual contact pads of same polarity and between contacts of one polarity of one solar cell to contact pads of the opposite polarity of a second solar cell. Those conductive pads also serve as protective pads to avoid chemical or physical attack of the conductive

layer below apertures for example during an etching process effected during further processing.

The proposed process of the claimed invention for establishing the individualized conducting contact structure allows to use only 4 main process steps by depositing a conductive layer or layer stack, depositing an isolation resist layer, depositing the contact pads and an etching step to separate the different type of contacts and to provide a solar cell. Included, even if not mentioned in detail are additional steps like drying and/or curing of the resin layer as well as rinsing and drying steps used in a chemical etching process.

Also, the method of the claimed invention is based on a low-cost deposition of an isolation resist layer. The deposition of the isolation resist layer can be done for example by screen-printing or ink-jet printing.

In embodiments the isolation resist layer can for example be a resin, a lacquer, a printable thermoplastic polymer or the like. The isolation resist layer can be opaque, or at least partially transparent or at least partially reflective in at least a certain predetermined wavelength range.

Furthermore, the isolation resist layer guarantees an electrical separation of conduction wires or ribbons that are used to interconnect pads of one polarity on a first cell and/or contact pads of one polarity of one cell with contact pads of a second cell either having the same polarity for parallel connection or an opposite polarity for series connection.

Furthermore, the isolation resist layer guarantees an electrical separation of conduction wires or ribbons that are used to interconnect pads of one polarity from the pads of the opposite polarity by preventing the electrical contact between the wires or ribbons to the conductive layer underneath.

In an embodiment, said conductive layer comprises at least a transparent conductive oxide layer or at least one metallic layer or a combination thereof.

In an embodiment said transparent conducting oxide (TCO) layer of the conductive layer is made of conductive oxides of one of the materials: Zinc (Zn), Tin (Sn), Indium (In), Tungsten (W), or a combination of them. For higher conductivity those metal oxides can be doped by dopants like Aluminum, Boron, Gallium, Fluorine.

layer. Keeping the whole TCO layer intact allows to provide efficient electrical carrier collection on one side and at the same time provide sufficient openings to assure bi-faciality and/or back-reflectance of the solar cell.

In an embodiment the method comprises, a Step H consisting in connecting the conductive pads by respective electrically conducting ribbons and/or wires.

These conductors being used to interconnect conductive pads or contacts of same polarity on the photovoltaic device. These conductors can also be used to interconnect conductive contacts of a first polarity of a first device with the conductive contacts of second polarity of a second cell for series interconnection. These conductors can also be used to interconnect contacts pads of a first polarity of a first device with the conductive contacts of a first polarity of a second cell for parallel interconnection.

~~In a second aspect the invention is achieved by~~ According to a second aspect of the present invention, there is provided an interdigitated back contact (IBC) photovoltaic device having first-type charge collecting structures and second-type charge collecting structures. The photovoltaic device comprises a substrate comprising a semiconducting structure defining a front surface to the side of said substrate and a back surface opposite to said front surface, the semiconducting structure comprising, on the back side of the substrate, a first type doped semiconducting structure consisting in a plurality of n- or p-doped portions and a second type doped semiconducting structure , being of the other doped-type of said first-type doped structure,

The photovoltaic device comprises further a layer stack arranged on said ~~on the~~ semiconducting structures. The layer stack comprises;

- a conductive layer arranged on said semiconducting structures;
- a patterned isolating resist layer, defining a back surface to the side away from said substrate arranged on said conductive layer, comprising contact apertures and isolation apertures and conducting pads are provided on said resist layer in said contact apertures where the contact pads electrically contact the conductive layer and can jut out of the contact apertures

In the photovoltaic device, trenches are provided in the conductive layer, to separate electrically the first type charge collecting structures F1 from second type charge collecting

structures F2. The trenches are defined by isolation of apertures realized in the isolation resist layer. The trenches have a depth extending from the back surface of said patterned isolating resist layer to at most the back surface of said first or second-type doped semiconducting structures.

In an embodiment, said conductive layer comprises at least one transparent conductive oxide (TCO) layer or at least one metallic layer or a combination thereof.

In an embodiment, said trenches comprise a succession of openings of the different layers of said layer stack.

In an embodiment, the lateral width of the opening in said at least one transparent conductive oxide (TCO) layer is smaller than any of the lateral widths of the layers of said conductive layer.

In an embodiment, the lateral width of the opening in said at least one transparent conductive oxide (TCO) layer is greater than at least one of the lateral widths of the layer of said conductive layer.

In an embodiment, said conductive layer comprises on said at least one transparent conductive oxide (TCO) layer, and at least one of: a metallic layer, a second metallic layer, an additional metallic layer.

In an embodiment, said additional metallic layer is in contact with said at least one transparent conductive oxide (TCO) layer.

In an embodiment, the lateral width of the opening in said at least one transparent conductive oxide layer is smaller than at least one of the lateral widths of the openings of the layers of said conductive layer.

In an embodiment, the lateral width of the aperture in said additional metallic layer is smaller than the lateral width of the aperture in said at least one metallic layer.

In an embodiment, the claimed invention is achieved with an IBC photovoltaic device, where the semiconducting structures provide a heterojunction contact with the crystalline silicon substrate.

In an embodiment, the claimed invention is a tunnel-junction heterojunction type IBC photovoltaic device, where the first type doped semiconducting structures are locally deposited on the back side of the cell and the second type doped semiconducting structure is deposited on the back side of the device by at least partially covering also

the first type doped semiconducting structures. With this process a tunnel-junction is established in the contact zones of first and second type doped semiconducting structures.

In an embodiment an additional protective layer is deposited on top of the resin layer at least in areas of the trenches that separate first type charge collecting structures F1 from second type charge collecting structures F2. In an advantageous implementation of the claimed invention the protective layer is deposited on the full back side of the photovoltaic device with a thickness that allows electrical through-contacting of the contact pads via the protective layer. The protective layer may be for example a SiN layer.

In an embodiment, the interdigitated back contact IBC photovoltaic device 1 comprises a plurality of openings extending from the resist layer back surface to at least a predetermined depth d2 in said conductive layer, said openings, having lateral dimensions in directions x, y between 2um and the overall dimension of the wafer substrate and can have any form, like round, elliptical, square, hexagonal, or star-like holes, lengthy trenches or even a combination of different forms

In an embodiment, at least two interdigitated back contact (IBC) photovoltaic cells are interconnected by conductors. The conducting pads of the first type of the first cell are connected to conducting pads of the first type of the second cell for parallel interconnection or to second type of the second cell for series interconnection.

According to a third aspect of the present invention, there is provided a photovoltaic system comprising at least two interdigitated back contact (IBC) photovoltaic devices as described in the second aspect that are interconnected by conductors and wherein conducting pads of the first type of the first cell are connected to conducting pads of the second type of the second cell by that establishing a series connection of accordingly connected devices and/or wherein conducting pads of the first or second type of the first cell are connected respectively to conducting pads of the first or second type of the second cell and by that establishing a parallel connection of accordingly connected devices.

Brief description of the drawings

The present invention will now be described in reference to the enclosed drawings where:

– Figure 1 illustrates a perspective view of a realized junction IBC device according to the invention. The silicon wafer texture has been removed in the Figures for clarity but is obviously present in a real device. Figure 1 and Figure 6 illustrates electrical contacts and the projection of charge collecting fingers in

Claims

1. A method for manufacturing an interdigitated back contact (IBC) photovoltaic device ~~1~~ comprising a substrate ~~(2)~~ defining a plane ~~(X-Y)~~ and, parallel to said plane ~~(X-Y)~~, a longitudinal ~~(A-A)~~ and a lateral ~~(B-B)~~ direction, orthogonal to said ~~lateral~~ longitudinal direction ~~(A-A)~~ and comprising the steps (A-E) of:
   - Step A: providing a substrate ~~(2)~~ of a first- or second type doping being an n-type or a p-type doping and having a front side ~~(2a)~~ and a back side ~~(2b)~~ and realizing on said back side ~~(2b)~~ a semiconducting structure ~~(6)~~ defining a front surface ~~(6a)~~ to the side of said substrate and a back surface ~~(6b)~~ opposite to said front surface ~~(6a)~~, the semiconducting structure ~~(6)~~ comprising individual doped portions ~~(6')~~ of said first type doping and a doped semiconducting structure ~~(6'')~~ of a second-type, being of the other type than said first type, to provide alternating electrical charge-types of semiconducting contacts;~~,~~
   - Step B: realizing a conductive layer ~~(100)~~ on top of said doped semiconducting structures ~~(6')~~ and ~~(6'')~~;
   - Step C: realizing a patterned isolation resist layer ~~(14)~~, having a back surface ~~(140)~~, onto said conductive layer ~~(100)~~, and so that the formed resist layer ~~(14)~~ comprises resist parts ~~(14a)~~ and contact apertures ~~(14b)~~ and isolation apertures ~~(14c)~~, and so that the patterns of the isolation resist layer are aligned relative to said semiconducting structures;
   - Step D: applying a plurality of conductive pads ~~(16, 16')~~ onto said isolation resist layer ~~(14)~~, and so that the conductive pads ~~(16, 16')~~ fill said contact apertures ~~(14b)~~ making electrical contact to said conductive layer ~~(100)~~,
   - Step E: etching of the conductive layer ~~(100)~~ in areas specified by isolation apertures ~~(14c)~~ in the isolation resist layer ~~(14)~~ and realize trenches ~~(20)~~, extending between said back surface to at most the back surface of said semiconducting structure, to form electrically separated first type charge collecting structures ~~(F1)~~ and second type charge collecting structures ~~(F2)~~.

2. The method according to claim 1 wherein said conductive layer ~~(100)~~ comprises at least one transparent conductive oxide (TCO) ~~(8)~~ or at least one metallic layer ~~(10)~~ or a combination thereof.
3. The method according to claim 2 wherein said transparent conducting oxide layer ~~(8)~~ is made of one of the oxides of the metals: Indium (In), Zinc (Zn), Tin (Sn), Tungsten (W) or a combination of them.
4. The method according to claim 2 wherein the material of said at least one metallic layer is chosen among: Copper (Cu), Silver (Ag), Aluminium (Al), Nickel (Ni), Zinc (Zn), Tin (Sn) Chromium (Cr), Beryllium (Be), Gold (Au) or an alloy thereof.
5. The method according to any one of claims 1 to 4 wherein the material of said conductive pads ~~(16, 16')~~ comprises an electrically conducting compound or paste.
6. The method according to any of claims 1 to 5 wherein optionally a step F is performed consisting in the realization of an additional isolation layer ~~(50)~~ on the back side of the photovoltaic device ~~(1)~~ by filling at least the trenches ~~(20)~~.
7. The method according to any one of claims 1 to 6 wherein optionally a step G is performed consisting in the realization of a plurality of additional openings ~~(200)~~, defined by apertures ~~(14d)~~ in the isolation resist layer ~~(14)~~, to at least a predetermined depth (d200) in said conductive layer ~~(100)~~.
8. The method according to any one of claims 1 to 7 comprising, a step H consisting in connecting the conductive pads ~~(16, 16')~~ by respective electrically conducting ribbons and/or wires ~~(18, 18')~~.
9. An interdigitated back contact (IBC) photovoltaic device ~~(1)~~ having first-type charge collecting structures ~~(F1)~~ and second-type charge collecting structures ~~(F2)~~, the photovoltaic device ~~(1)~~ comprising a substrate ~~(2)~~ comprising a semiconducting structure ~~(6)~~ defining a front surface ~~(6a)~~ to the side of said substrate and a back surface ~~(6a)~~ opposite to said front surface ~~(6a)~~, the semiconducting structure ~~(6)~~ comprising, on the back side of the substrate ~~(2)~~, a first-type-doped semiconducting structure consisting in a plurality of n- or p-doped portions ~~(6')~~ and a second-type doped semiconducting structure ~~(6'')~~, being of the other doped-type of said first-type doped structure,

wherein a layer stack ~~(100, 14)~~ is arranged on said semiconducting structures ~~(6', 6'')~~, the layer stack ~~(100, 14)~~ comprising:

- a conductive layer ~~(100)~~ arranged on said semiconducting structures ~~(6', 6'')~~;
- a patterned isolating resist layer ~~(14)~~, defining a back surface to the side away from said substrate, arranged on said conductive layer ~~(100)~~, comprising contact apertures ~~(14b)~~ and isolation apertures ~~(14c)~~ and conducting pads ~~(16, 16')~~ are provided on said resist layer ~~(14)~~ in said contact apertures ~~(14b)~~ where the contact pads electrically contact the conductive layer ~~(100)~~ and can jut out of the contact apertures ~~(14b)~~,

and wherein further:

trenches ~~(20)~~ are provided in the conductive layer ~~(100)~~, to separate electrically the first-type charge collecting structures ~~(F1)~~ and the second-type charge collecting structures ~~(F2)~~, said trenches ~~(20)~~ being specified by said isolation apertures ~~(14c)~~ in the isolation resist layer ~~(14)~~,

wherein the trenches ~~extending~~ extend between said back surface ~~(140)~~ to at most the back surface ~~(6b)~~ of said semiconducting structure ~~(6)~~.

10. The interdigitated back contact (IBC) photovoltaic device ~~(1)~~ according to claim 9 wherein said conductive layer ~~(100)~~ comprises at least one transparent conductive oxide (TCO) layer ~~(8)~~ or at least one metallic layer ~~(10, 11, 12)~~ or a combination thereof.

11. The interdigitated back contact (IBC) photovoltaic device ~~(1)~~ according to any claims 9 or 10 wherein said trenches ~~(20)~~ comprise a succession of openings ~~(20', 20'', 20''', 20'''', 20ᵛ)~~ of the different layers ~~(14, 12, 10, 8, 14, 11)~~ of said layer stack ~~(100, 14)~~, said openings having lateral widths.

12. The interdigitated back contact (IBC) photovoltaic device ~~(1)~~ according to claim 11 wherein the lateral width (A4) of the opening ~~(20'''')~~ in said at least one transparent conductive oxide (TCO) layer ~~(8)~~ is smaller than at least one of the lateral widths (A2, A3, A5) of the openings of the layers of said conductive layer ~~(100)~~.

13. The interdigitated back contact (IBC) photovoltaic device ~~1~~ according to any one of claims 9 to 12 wherein said conductive layer ~~(100)~~ comprises, on said at least

one transparent conductive oxide (TCO) layer ~~(8)~~, at least one metallic layer ~~(10)~~ and at least one additional metallic layer ~~(11)~~, of which one is in contact with said at least one transparent conductive oxide (TCO) layer ~~(8)~~, the lateral width (A5) of the aperture ~~(20''')~~ in said at least one additional metallic layer ~~(11)~~ being smaller than the lateral width (A3) of the aperture ~~(20''')~~ in said at least one metallic layer ~~(10)~~.

14. The interdigitated back contact (IBC) photovoltaic device ~~1~~ according any one of claims 9 to 13, wherein the semiconducting structures ~~(6', 6'')~~ provide a heterojunction contact with the crystalline silicon substrate ~~(2)~~.

15. The interdigitated back contact (IBC) photovoltaic device ~~1~~ according to any one of claims 9 to 14~~-~~, wherein the first type doped semiconducting structures ~~(6')~~ are locally deposited on the back side of the cell and a second type doped semiconducting structure ~~(6'')~~ is deposited on the back side of the device by at least partially covering also the first type doped semiconducting structures ~~(6')~~, providing a tunnel-junction in the contact zones of first ~~(6')~~ and second type doped semiconducting structure ~~(6'')~~.

16. The interdigitated back contact (IBC) photovoltaic device to any of claim 9 to 15, wherein an additional insulating layer ~~(50)~~ is deposited on the back side of the photovoltaic device, at least within the trenches ~~(20)~~.

17. The interdigitated back contact (IBC) photovoltaic device ~~(1)~~ according to any claim of 9 to 16, comprising a plurality of openings ~~(200)~~ extending from the resist layer back surface ~~(140)~~ to at least a predetermined depth (d2) in said conductive layer ~~(100)~~.

18. A photovoltaic system comprising at least two interdigitated back contact (IBC) photovoltaic devices according to any one of claims 9 to 17 that are interconnected by conductors and wherein conducting pads of the first type ~~(16)~~ of the first cell are connected to conducting pads of the second type ~~(16')~~ of the second cell by that establishing a series connection of accordingly connected devices and/or wherein conducting pads of the first or second type ~~(16, 16')~~ of the first cell are connected respectively to conducting pads of the first or second type ~~(16, 16')~~ of the second cell and by that establishing a parallel connection of accordingly connected devices.