

DESCRIPTION

Solar cell manufacturing

This application claims the priorities of French patent applications number 2007382, filed on July 13, 2020, entitled "procédé de fabrication de contacts passives pour cellules solaires IBC" and number 2011026, filed on October 28, 2020, entitled "Fabrication de cellules solaires", the contents of which are incorporated by reference to the maximum extent allowable by law.

Technical field

[0001] The present disclosure relates generally to solar cells and more particularly to back side contact solar cell structures and manufacturing process.

Background art

[0002] Solar cells are devices for converting sunlight into electrical energy. Generally, solar cells structure is based on the presence of p-type region and n-type region on the same semiconductor substrate. In a back side contact solar cell, each region is coupled to metal contacts on the back side of the solar cells to allow an external electrical circuit or device to be coupled to and be powered by the solar cell as described in US2016/0351737 and in US7468485.

Summary of Invention

[0003] There is a need to improve current solar cells and its process, particularly to decrease the process time.

[0004] One embodiment addresses all or some of the drawbacks of known solar cells and their process of manufacturing.

[0005] One embodiment provides a method of manufacturing a solar cell, the method comprising, in the order:

forming a tunnel oxide over, at least, one surface of a semiconductor substrate;

forming a first layer doped with a first-type conductive dopant over the tunnel oxide;

forming a mask on the first doped layer;

forming a second layer doped with a second-type conductive dopant over the mask; and

doping at least one first region of the first doped layer using a laser, through the second layer doped with the second-type conductive dopant.

[0006] According to an embodiment, the method comprises forming trenches extending in the second layer, the mask, the first doped layer and the tunnel oxide after the formation of the second layer.

[0007] According to an embodiment, trenches separate the first region of the first doped layer from second regions of the first doped layer.

[0008] According to an embodiment, the method comprises texturing of the semiconductor substrate on another surface.

[0009] According to an embodiment, the method comprises forming a passivation film over the first doped layer, the passivation layer recovering the inside of trenches.

[0010] One embodiment provides an interdigitated-back-contact or IBC solar cell obtained by the method as described above.

[0011] One embodiment provides a solar panel comprising IBC solar cells.

Brief description of drawings

[0012] The foregoing features and advantages, as well as others, will be described in detail in the following description of specific embodiments given by way of illustration and not limitation with reference to the accompanying drawings, in which:

[0013] Figure 1 illustrates a sectional view illustrating an example of a solar cell;

[0014] Figure 2 illustrates a sectional view illustrating a step of an example of method of manufacturing the solar cell illustrated in Figure 1;

[0015] Figure 3 illustrates another step of the manufacturing method of Figure 2;

[0016] Figure 4 illustrates another step of the manufacturing method of Figure 2;

[0017] Figure 5 illustrates another step of the manufacturing method of Figure 2;

[0018] Figure 6 illustrates another step of the manufacturing method of Figure 2;

[0019] Figure 7 illustrates another step of the manufacturing method of Figure 2;

[0020] Figure 8 illustrates another step of the manufacturing method of Figure 2;

[0021] Figure 9 illustrates another step of the manufacturing method of Figure 2;

[0022] Figure 10 illustrates another step of the manufacturing method of Figure 2;

[0023] Figure 11 illustrates another step of the manufacturing method of Figure 2;

[0024] Figure 12 illustrates another step of the manufacturing method of Figure 2;

[0025] Figure 13 illustrates another step of the manufacturing method of Figure 2;

[0026] Figure 14 illustrates another step of the manufacturing method of Figure 2;

[0027] Figure 15 illustrates another step of the manufacturing method of Figure 2;

[0028] Figure 16 illustrates another step of the manufacturing method of Figure 2;

[0029] Figure 17 illustrates a sectional view illustrating a solar cell in accordance with an embodiment of the present description;

[0030] Figure 18 illustrates a sectional view illustrating a step of a method of manufacturing a solar cell in accordance with the embodiment of the present description;

[0031] Figure 19 illustrates another step of the manufacturing method of Figure 18;

[0032] Figure 20 illustrates another step of the manufacturing method of Figure 18;

[0033] Figure 21 illustrates another step of the manufacturing method of Figure 18;

[0034] Figure 22 illustrates another step of the manufacturing method of Figure 18;

[0035] Figure 23 illustrates another step of the manufacturing method of Figure 18;

[0036] Figure 24 illustrates another step of the manufacturing method of Figure 18;

[0037] Figure 25 illustrates another step of the manufacturing method of Figure 18;

[0038] Figure 26 illustrates another step of the manufacturing method of Figure 18; and

[0039] Figure 27 illustrates another step of the manufacturing method of Figure 18.

Description of embodiments

[0040] Like features have been designated by like references in the various figures. In particular, the structural and/or functional features that are common among the various embodiments may have the same references and may dispose identical structural, dimensional and material properties.

[0041] For the sake of clarity, only the operations and elements that are useful for an understanding of the embodiments described herein have been illustrated and described in detail.

[0042] Unless indicated otherwise, when reference is made to two elements connected together, this signifies a direct connection without any intermediate elements other than conductors, and when reference is made to two elements coupled together, this signifies that these two elements can be connected or they can be coupled via one or more other elements.

[0043] In the following disclosure, unless indicated otherwise, when reference is made to absolute positional qualifiers, such as the terms "front", "back", "top", "bottom", "left", "right", etc., or to relative positional qualifiers, such as the terms "above", "below", "higher", "lower", etc., or to qualifiers of orientation, such as "horizontal", "vertical", etc., reference is made to the orientation shown in the figures.

[0044] Unless specified otherwise, the expressions "around", "approximately", "substantially" and "in the order of" signify within 10 %, and preferably within 5 %.

[0045] Figure 1 is a sectional view illustrating an example of a solar cell.

[0046] The solar cell shown in Figure 1 is made of a semiconductor substrate 10 having a front side portion intended to receive solar radiation during normal operation

and a back side portion where metal contacts of the solar cell are formed. The solar cell has a textured front side covered by a doped layer 37.

[0047] The solar cell of Figure 1 includes first regions 32 of a first type of conductivity, such as p-type regions, and second regions 36 of a second type of conductivity, such as n-type regions, formed in an undoped layer 30B over the back side of the substrate 10. A tunnel oxide layer 20B may be formed on the back side of the substrate 10, more precisely, between the substrate 10 and the undoped layer 30B. Layer 37 is of the second type of conductivity.

[0048] Metal contacts 41 are connected to regions 32 and 36 to allow external circuits and devices to receive electrical power from the solar cell.

[0049] Solar cell of Figure 1 may include passivation layers 38, 39, 40 to protect the structure from outside electrical damages.

[0050] Figures 2 to 16 are sectional views illustrating steps of an example of method of manufacturing the solar cell illustrated in Figure 1.

[0051] The process of manufacturing the solar cell shown in Figure 1 may comprises:

- preparation (Figure 2) of the semiconductor substrate 10;
- formation (Figure 3) of a tunnel oxide layer 20F on a front side 101 of the substrate 10 and of another tunnel oxide layer 20B on a back side 103 of the substrate 10;
- formation of a semiconductor layer 30F on the front side of layer 20F and another semiconductor layer 30B on the back side of layer 20B;

- formation (Figure 4) of a layer 31 on the back side of layer 30B made of a doped layer, which is formed over the entire layer 30B and an undoped layer formed over the entire doping layer. The doping layer include a first-type (p or n) conductive dopant;
- formation (Figure 5) of openings 310 in layer 31 using, for example, a wet etching process;
- formation (Figure 6) of areas 32 in the layer 30B by the thermal diffusion of dopants of layer 31 in the layer 30B by using a laser;
- deposition (Figure 7) of a masking layer 33 all around the structure;
- removal (Figure 8) of the masking layer 33 from the front side of the structure and more precisely from the front side of layer 30F and from the lateral sides of layer 30F, layer 20F and a part of the substrate 10;
- removal (Figure 9) of layer 20F and layer 30F and texturing process of the front side of layer 30F;
- formation (Figure 10) of openings 34 in the masking layer 33;
- treatment (Figure 11) under a gas atmosphere 35 containing a second-type conductive dopant in order to form an area 36 in the layer 30B and a layer 37 on the front side of the substrate 10;
- removal (Figure 12) of the masking layer 33;
- thermal treatment (Figure 13) in order to diffuse the dopant of the area 36 in all the depth of layer 30B;
- formation (Figure 14) of a passivation and anti-reflection film 38 in the front side of layer 37;

- formation (Figure 15) of a passivation film 39 in the back side of the structure and a passivation film 40 in lateral sides of the structure; and
- formation (Figure 16) of electrodes 41 on the back side of the structure by a step of wet etch of the layer 39 and a step of metal deposition.

[0052] Figure 17 is a sectional view illustrating a solar cell in accordance with an embodiment of the present description.

[0053] The solar cell shown in Figure 17 is made of a semiconductor substrate 50 having a front side portion intended to receive solar radiations during normal operation and a back side portion where metal contacts to the solar cell are formed. The solar cell has a textured front side covered by a doped layer 64.

[0054] The solar cell of Figure 17 includes one or more regions 541 of a first-type of conductivity, such as p-type regions, and one or more regions 66 of a second-type of conductivity, such as n-type regions, formed over the back side of the substrate 50. A tunnel oxide layer 52 may be formed on the back side of the substrate 50, more precisely, between the substrate 50 and the regions 541, 66.

[0055] Metal contacts 76, 78 are, respectively, connected to regions 541 and 66 to allow external circuits and devices to receive electrical power from the solar cell.

[0056] Solar cell of Figure 17 may include passivation layers 70, 72, 74 to protect the structure from outside electrical damages.

[0057] Moreover, the solar cell shown in Figure 17 may include, between region 541 and region 66, trenches 60 and, in the substrate 50, a low depth of the doped substrate 68 with the second-type conductive dopants.

[0058] Figure 18 illustrate a step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0059] In the present embodiment, the substrate 50 is a semiconductor substrate, for example a silicon wafer, preferably doped with an n-type dopant such as Phosphorus (P), or a p-type dopant such as Gallium (Ga) and Boron (B).

[0060] Substrate 50 has a front side 501 and a back side 503. Front side 501 is the side of the solar cell intended to receive solar radiations. Substrate 50 is thinned to a thickness of, for example, about 240 μm using a process that also etches damages from the surfaces of the wafer (Saw Damage Etching - SDE).

[0061] Figure 19 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0062] In Figure 19, a doped layer 54, for example a p doped polysilicon layer, is formed over a tunnel oxide layer 52.

[0063] The tunnel oxide layer 52 is formed over the back side 503 and, for example, over the front side of the substrate 50. Tunnel oxide layer 52 is formed in order to be thin enough to increase the probability of electrons directly tunnelling across tunnel oxide layer 52. Tunnel oxide layer 52 may have a thickness of about 7 Angstroms to about 20 Angstroms. In one embodiment, tunnel oxide layer 52 has a thickness of about 10 Angstroms. Tunnel oxide layer 52 may be formed by, for example, thermal growth or chemical deposition (e.g., plasma enhanced chemical vapor deposition (PECVD) or low pressure chemical vapor deposition (LPCVD)). Tunnel oxide layer 52 may be formed using an ozone oxidation process, which involves dipping substrate 50 in a bath comprising ozone suspended in deionized water. For example, substrate 50 may first undergo a wet etch using potassium hydroxide to thin substrate 50,

then a rinse-clean cycle, then the ozone oxidation process to form tunnel oxide layer 52 all in the same equipment. During the ozone oxidation process, a layer of tunnel oxide grows on both sides of substrate 50.

[0064] According to an alternative embodiment, tunnel oxide layer 52 may also be formed using other processes without detracting from the merits of the present description.

[0065] Polysilicon layer 54 may have a thickness of about 2000 Angstroms. Polysilicon layer may be deposited on tunnel oxide 52 by PECVD or LPCVD using boron trichloride (BCl_3) or diborane (B_2H_6) with silane (SiH_4).

[0066] In Figure 19, after the deposition of the layer 54, a masking layer 56 is formed over and under layer 54 in order to fully wrap the structure. Masking layer 56 will be used in a subsequent etch and laser process (Figures 23 to 25) exposing portions of layer 54.

[0067] In Figure 19, a layer 57 is formed over and under masking layer 56 in order to fully wrap the structure. In one example, layer 57 may be doped with an n-type dopant. In one embodiment, layer 57 is made of a phosphosilicate glass (PSG), for example, by an atmospheric reaction of phosphine (PH_3) and tetraethyl orthosilicate (TEOS).

[0068] In Figure 19, another masking layer 58 is formed over layer 57 in order to fully wrap the structure.

[0069] Masking layers 56 and 58 and layer 57 may be formed by, for example, thermal growth or chemical deposition (PECVD or LPCVD). However, various other methods may be applied to form masking layers 56, 58 and layer 57.

[0070] Masking layers 56, 58 may be formed of a material, which is selected for being an undoped material having no conductive dopant and for its ability of preventing the

diffusion of the n conductive dopant. In one example, masking layers 56, 58 may be a single layer including a silicon oxide (SiO_x), a silicon nitride (SiH_x), a silicon oxynitride (SiO_xN_y), intrinsic amorphous silicon, a silicon carbide (SiC), or a combination of these materials. In particular, when masking layers 56, 58 are a single layer formed of a silicon carbide, masking layers 56, 58 may effectively prevent the diffusion of the dopant.

[0071] Figure 20 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0072] In Figure 20, masking layers 56, 58 and layer 57 are removed from the front side of the structure (from the side of front side 501 of the substrate 50). If masking layer 56, 58 and layer 57 are formed in the previous step by PECVD, this step of removal can be skipped.

[0073] Figure 21 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0074] In one embodiment, the masking layers 56, 58, layer 57, layer 52, layer 54 and a part of the substrate 50 are removed from the back side (from the side of back side 503 of the substrate 50) in some areas in order to create trenches 60. The trenches 60 are, for example, made by using a laser.

[0075] In one other embodiment, the masking layers 56, 58 and layer 57 are removed from the back side (from the side of back side 503 of the substrate 50) in some areas in order to create apertures in one step. The apertures are, for example, made by using a laser. In another step, masking layers 56, 58 and layer 57 are used in etching p-type dopant layer 54 and tunnel oxide layer 52. In the same embodiment, the layer 54, layer 52 and the substrate 50 are patterned using a wet etch

process comprising buffered hydrofluoric acid, potassium hydroxide and isopropyl alcohol or a solution of TMAH (TetraMethylAmmonium Hydroxid). The wet etch process etches portions of the layer 54, the tunnel oxide layer 52 and the substrate 50 not covered by the masking layers 56, 58 and layer 57. The wet etch process etches in order to create trenches 60 which extend from the apertures into the layer 54, the tunnel oxide layer 52 and the substrate 50. Regions 541 and 542 are formed in the layer 54.

[0076] In Figure 21, two trenches 60 are made on the masking layers 56, 58, layer 57, layer 54, layer 52 and the substrate 50, however, the number of trenches 60 can be different than two. Each trench 60 has a width comprising between 30 nm and 200 μm .

[0077] Figure 21 illustrates also the doping of areas 542 in order to create regions 66. The doping process of areas 52 is made by using a laser.

[0078] The laser may have a wavelength of 1064 nm or less. This is because it is difficult to produce a laser having wavelength exceeding 1064 nm. That is, all of the wavelength of infrared light, ultraviolet light and visible light may be used as the laser. At this time, in one example, the laser may be a laser having wavelength within a range from 500 nm to 650 nm, that is a green laser.

[0079] Figure 22 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0080] In Figure 22, front side 501 of substrate 50 is textured. Front side 501 may be textured using a wet etch process or another chemical process comprising, for example, potassium hydroxide and isopropyl alcohol or a solution of TMAH (Tetramethylammonium hydroxid). The wet etch process textures front side 501 with random pyramids, thereby

advantageously improving solar radiation collection efficiency.

[0081] The present embodiment illustrates that the front surface 501 of the semiconductor substrate 50 is textured at this step. However, the embodiment of the present description is not limited thereto.

[0082] Figure 23 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0083] The structure shown in Figure 22 is, in Figure 23, put in a gas atmosphere 62 containing a n-type conductive dopant. The gas atmosphere 62 may be created using various gases containing the n-type conductive dopant. In one example, when the conductive dopant is phosphorus (P), the gas atmosphere 62 may include phosphoryl chloride (POCl_3).

[0084] At this time, the front surface 501 of the semiconductor substrate 50 may be doped with the n-type conductive dopant. Thereby, a front surface field 64 area may also be formed during the doping process. However, the embodiment of the present description is not limited thereto. Thus, in the doping process, an anti-diffusion film may be formed over the front surface 501 of the semiconductor substrate 50 so that no front surface field 64 area is formed in the doping process. In this instance, the front surface field area 64 may be formed in a separate process selected from among various processes including, for example, ion implantation, thermal diffusion, and laser doping.

[0085] During the steps illustrated by Figure 23, surface field areas 64 and regions 68 are realised during the same doping process under POCl_3 .

[0086] After this step the structure is, for example, annealed.

[0087] Figure 24 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0088] At this time, masks 56, 58, and layer 57 are removed and the structure leave the gas atmosphere 62.

[0089] Figure 25 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0090] In Figure 25, an insulation film 70 is formed on the front surface of the semiconductor substrate 50. Insulation films 70 include a front surface passivation film and an anti-reflection film which are formed on the front surface of the layer 64. For example, the front surface passivation film and the anti-reflection film are formed over the entire front surface of the layer 64. The front surface passivation film and the anti-reflection film may be formed using various methods such as, for example, vacuum deposition, chemical vapor deposition, spin coating, screen printing, or spray coating. The sequence of forming the front passivation film and the anti-reflection film is not defined.

[0091] Figure 26 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0092] In Figure 26, insulation films 72 and 74 are respectively formed on the back surface and on the lateral surface of the structure.

[0093] For example, the back surface passivation film 72 is formed over the entire back surface of the structure. The back surface passivation film 72 may be formed using various methods such as, for example, vacuum deposition, chemical vapor deposition, spin coating, screen printing, or spray coating.

[0094] Figure 27 illustrate another step of manufacturing a contact solar cell in accordance with the embodiment of the present description.

[0095] Figure 27 illustrates formation of first and second electrodes 76 and 78, which are respectively connected to the conductive regions 541 and 66.

[0096] The first and second electrodes 76 and 78 may be formed by applying paste, to the back surface by, for example, screen printing, and thereafter performing, for example, fire-through or laser firing contact. The back surface etches, for example, the passivation film 72 before the deposition of metal, in order to create metallizations.

[0097] An advantage of the second embodiment and implementation modes is that the tunnel oxide, doped layer and mask deposition is realised in one step contrary to the first embodiment.

[0098] An advantage of the second embodiment and implementation modes is that the manufacturing process of solar cells is shorter and cheaper than the first embodiment.

[0099] Various embodiments and variants have been described. Those skilled in the art will understand that certain features of these embodiments can be combined and other variants will readily occur to those skilled in the art.

[0100] Finally, the practical implementation of the embodiments and variants described herein is within the capabilities of those skilled in the art based on the functional description provided hereinabove.

CLAIMS

1. A method of manufacturing a solar cell, the method comprising, in the order:
 - forming a tunnel oxide (52) over, at least, one surface (503) of a semiconductor substrate (50);
 - forming a first layer (54) doped with a first-type conductive dopant over the tunnel oxide;
 - forming a mask (56) on the first doped layer;
 - forming a second layer (57) doped with a second-type conductive dopant over the mask; and
 - doping at least one first region (542, 66) of the first doped layer using a laser, through the second layer doped with the second-type conductive dopant.
2. A method according to claim 1, comprising forming trenches (60) extending in the second layer (57), the mask (56), the first doped layer (54) and the tunnel oxide (50) after the formation of the second layer.
3. The method according to claim 2, wherein trenches (60) separate the first region (542, 66) of the first doped layer from second regions (541) of the first doped layer.
4. The method according to any of claims 2 or 3, comprising forming a passivation film (72) over the first doped layer, the passivation layer recovering the inside of trenches.
5. The method according to any of claims 1 to 4, comprising texturing of the semiconductor substrate (50) on another surface (501).
6. An IBC solar cell obtained by the method according to anyone of claims 1 to 5.

7. A solar panel comprising IBC solar cells according to claim 6.