a conductive contact disposed on the emitter region and comprising a conductive layer in contact with the emitter region, the conductive layer comprising a metal paste portion mixed with an adhesion layer portion, the metal paste portion including silicon, wherein the adhesion layer portion mixes with the silicon in the metal paste portion so as to adhere the conductive layer to the emitter region disposed above the substrate.

[0003b] According to the second aspect of the invention, a solar cell is provided, comprising

a substrate having a diffusion region at or near a surface of the substrate; and

a conductive contact disposed above the diffusion region and comprising a conductive layer in contact with the diffusion region, the conductive layer comprising a metal paste portion mixed with an adhesion layer portion, the metal paste portion including silicon, wherein the adhesion layer portion mixes with the silicon in the metal paste portion so as to adhere the conductive layer to the diffusion region at or near the surface of the substrate.

[0003c] According to the third aspect of the invention, a method of fabricating a solar cell is provided, comprising

forming an adhesion layer above an emitter region of a substrate;

forming a metal seed paste layer on the adhesion layer, the metal seed paste layer including silicon;

annealing the metal seed paste layer and the adhesion layer to form a conductive layer in contact with the emitter region of the substrate, wherein the adhesion layer mixes with the silicon in the metal seed paste portion so as to adhere the conductive layer to the emitter region of the substrate; and

forming a conductive contact for the solar cell from the conductive layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Figures 1A-1D illustrate cross-sectional views of various operations in a method of fabricating a contact for a solar cell, in accordance with an embodiment of the present invention.

[0005] Figure 2A illustrates a cross-sectional view of a portion of a solar cell having conductive contacts formed on emitter regions formed above a substrate, in

field passivation by heavy doping during deposition, (c) an amorphous silicon layer enhances adhesion of sputtered metal or printed metal to a wafer by forming a silicon-metal alloy, for example, a Si-Al alloy. Such an alloy can be used for the backside of an IBC cell, and also backside of front contact cells with back point contacts.

[0026] *In another aspect, as mentioned briefly above, aluminum is known to* form a better contact with p-type silicon than n-type silicon. Contact resistance of aluminum and n-type silicon is approximately 10 times higher than that of aluminum and ~~p~~n-type silicon for similar doping concentration. A thin p+ silicon layer can be formed on top of n+ diffusion layer, and then aluminum contact is formed on top of P+ layer instead of directly on top of n+ diffusion layer. The contact between aluminum and p+ silicon layer is ohmic, much better than aluminum and n+ diffusion. The junction between a p+ silicon layer and an n+ diffusion layer can further be used to form a tunneling junction when doping concentration is high, which behaves similar to ohmic contact. As a result, total contact resistance of Al/P+ layer/N+ diffusion can be better than contact resistance of Al/N+ diffusion (no P+ layer).

[0027] In an embodiment, a thin p+ silicon layer is formed on top of an n+ diffusion layer and, subsequently, an aluminum contact is formed on top of a p+ layer instead of directly on top of n+ diffusion layer. The contact between aluminum and p+ silicon layer is ohmic, much better than aluminum and n+ diffusion. The junction between p+ silicon layer and n+ diffusion layer can form a tunneling junction when doping concentration is high, which behaves similar to ohmic contact. As a result, total contact resistance of Al/p+ layer/n+ diffusion can be better than contact resistance of Al/n+ diffusion (no p+ layer). In one embodiment, the Al contact layer is formed by physical vapor deposition (PVD), printable paste or other suitable approaches. The n+ diffusion layer on silicon substrate can be single crystal or poly silicon. The thickness of p+ layer can be 5-100 nanometers, and doping concentration is >E19cm-3. The p+ layer can be amorphous silicon or poly silicon. For example, the p+ a-Si layer can be deposited by plasma enhanced chemical vapor deposition (PECVD). Embodiments may be implemented when contact between aluminum and n+ diffusion layer is a limitation factor, e.g., if doping concentration of n+ diffusion layer is low, or cannot be improved due to other constraints. When aluminum is formed by screen printed paste, the contact quality may be worse than a corresponding PVD film. Accordingly, in one embodiment, the above approach can be applied to printed seed metallization processes. If p+ layer cannot be used in some cases, additional heavily doped n+ layer

will help improve contact between Al/n-Si as well.

[0028] In another aspect, as mentioned briefly above, an a-Si layer is used as a sacrificial layer to mitigate silicon pitting. More specifically, to prevent pit formation on a silicon substrate, a layer of a-Si can be deposited on silicon substrate prior aluminum deposition. In one embodiment, the a-Si layer is preferably consumed by aluminum at elevated temperature, and the silicon substrate underneath is protected. In one such embodiment, a-Si is easier to be consumed by aluminum than single crystal silicon and ~~ploy~~poly silicon. A tunneling barrier (e.g., a 10-15 Angstrom thick SiO_2 layer) can also be formed between a silicon substrate and the a-Si layer. In a particular embodiment, an a-Si layer is deposited following contact opening and, subsequently, an aluminum-based paste is printed and fired. A single layer of a-Si can also be considered as a bARC layer for the resulting devices.

[0029] More generally, it is well known that inter-diffusion occurs very fast at silicon-aluminum interface at elevated temperature, by which pits forms on silicon substrate. When these pits forms within contact opening our solar cells, wafer lifetime is degraded and thus the resulting devices are degraded and, possibly, even shorted. Pit formation is typically eliminated by including some silicon in the aluminum film, typically ~1%. For example, in an embodiment, an aluminum sputtering target has 1% Si and is used to prevent pit formation during anneal. However, in a specific embodiment, a significantly greater amount of silicon (approximately 25%) is needed along with the aluminum particles to reduce pitting resulting from higher firing temperatures. Thus, in one embodiment, to prevent pit formation on a silicon substrate (single crystal or poly) at elevated temperature when aluminum layer is deposited or aluminum paste is printed, a layer of a-Si is deposited on the silicon substrate prior to aluminum paste deposition.

[0030] As described briefly above, in a first approach, a metal seed paste having enhanced adhesion can be used to ultimately fabricate contacts, such as back-side contacts, for a solar cell having emitter regions formed above a substrate of the solar cell. For example, Figure 2A illustrates a cross-sectional view of a portion of a solar cell having conductive contacts formed on emitter regions formed above a substrate, in accordance with an embodiment of the present invention.

[0031] Referring to Figure 2A, a portion of a solar cell 200A includes a patterned insulating layer 324 disposed above a plurality of n-type doped polysilicon regions 320, a plurality of p-type doped polysilicon regions 322, and on portions of a

the conductive contacts 328 are composed of metal and are formed by a deposition (the deposition described in greater detail below), lithographic, and etch approach.

[0046] Thus, in an embodiment, conductive contacts 328 are formed on or above a surface of a bulk N-type silicon substrate 300 opposing a light receiving surface 301 of the bulk N-type silicon substrate 300. In a specific embodiment, the conductive contacts are formed on regions (322/320) above the surface of the substrate 300, as depicted in Figure 3C. The fabrication of the conductive contacts can involve use of a mixture of an adhesion layer and a metal seed paste layer that forms by subjecting a paste layer/adhesion layer stack to and annealing process. Forming the conductive contacts can further include forming an electroless plated nickel (Ni) layer on the metal seed layer. Additionally, a copper (Cu) layer can be formed by electroplating on the Ni layer.

[0047] In an embodiment, forming the conductive layer involves first forming an adhesion layer on or above a substrate. The adhesion layer can be formed from a bottom anti-reflective coating (BARC) layer. In one such embodiment, the adhesion layer is composed of a layer of material such as, but not limited to, amorphous silicon (a-Si), doped silicon, silicon-rich silicon nitride, silicon dioxide (SiO_2) or silicon oxynitride (SiON). In a specific such embodiment, the adhesion layer is formed from a layer of P-type silicon. Forming the conductive layer next involves forming a metal seed paste layer on the adhesion layer. The metal seed paste layer can be composed of aluminum/silicon (Al/Si) particles, binders, frit, and a solvent. In one such embodiment, the Al/Si particles are composed of less than approximately 25% Si, with the remainder of the composition made up by Al. In one embodiment, if included, the binders can be composed of zinc oxide (ZnO), tin oxide (SnO), or both, and the frit can be composed of glass particles. Forming the conductive layer finally involves annealing the metal seed paste layer and the adhesion layer to form the conductive layer in contact with the emitter region of the substrate. Annealing the metal seed paste layer and the adhesion layer can involve mixing the metal seed paste layer and the adhesion layer. In one such embodiment, the annealing involves firing at a temperature below approximately 600 degrees Celsius.

[0048] In another aspect, embodiments are directed to improving ohmic contact between aluminum particles and Si at low firing temperatures. In one such embodiment, at least one of the elements of calcium (Ca), cerium (Ce), or magnesium (Mg) is added to the aluminum particles. By adding one or more of these species,

CLAIMS

What is claimed is:

1. A solar cell, comprising:

a substrate;

an emitter region disposed above the substrate; and

a conductive contact disposed on the emitter region and comprising a conductive layer in contact with the emitter region, the conductive layer comprising a metal paste portion mixed with an adhesion layer portion, the metal paste portion including silicon, wherein the adhesion layer portion mixes with the silicon in the metal paste portion so as to adhere the conductive layer to the emitter region disposed above the substrate.

2. The solar cell of claim 1, wherein the adhesion layer portion comprises a bottom anti-reflective coating (BARC) portion.

3. The solar cell of claim 2, wherein the adhesion layer portion further comprises a passivation layer portion.

4. The solar cell of claim 3, wherein the BARC portion comprises amorphous silicon, and the passivation layer portion comprises silicon nitride.

5. The solar cell of claim 1, wherein the adhesion layer portion comprises a material selected from the group consisting of amorphous silicon (a-Si), doped silicon, silicon-rich silicon nitride, silicon dioxide (SiO_2) and silicon oxynitride (SiON).

6. The solar cell of claim 1, wherein the metal paste portion comprises aluminum (Al) and the adhesion layer portion comprises silicon (Si), and the conductive layer comprises an Al-Si alloy.

7. The solar cell of claim 1, wherein the adhesion layer portion comprises a polymer glue.

8. The solar cell of claim 1, wherein the emitter region is an N-type emitter region, and the adhesion layer portion comprises P-type silicon.

9. The solar cell of claim 1, wherein the conductive layer has a thickness of approximately 2-10 microns, and wherein the conductive contact is a back contact of the solar cell comprising the conductive layer, an electroless plated nickel (Ni) layer disposed on the conductive layer, and an electroplated copper (Cu) layer disposed on the Ni layer.

10. A solar cell, comprising:

a substrate having a diffusion region at or near a surface of the substrate; and

a conductive contact disposed above the diffusion region and comprising a conductive layer in contact with the diffusion region, the conductive layer comprising a metal paste portion mixed with an adhesion layer portion, the metal paste portion including silicon, wherein the adhesion layer portion mixes with the silicon in the metal past portion so as to adhere the conductive layer to the diffusion region at or near the surface of the substrate.

11. The solar cell of claim 10, wherein the adhesion layer portion comprises a bottom anti-reflective coating (BARC) portion.

12. The solar cell of claim 11, wherein the adhesion layer portion further comprises a passivation layer portion.

13. The solar cell of claim 12, wherein the BARC portion comprises amorphous silicon, and the passivation layer portion comprises silicon nitride.

14. The solar cell of claim 10, wherein the adhesion layer portion comprises a material selected from the group consisting of amorphous silicon (a-Si), doped silicon, silicon-rich silicon nitride, silicon dioxide (SiO_2) and silicon oxynitride (SiON).

15. The solar cell of claim 10, wherein the metal paste portion comprises aluminum (Al) and the adhesion layer portion comprises silicon (Si), and the conductive layer comprises an Al-Si alloy.

16. The solar cell of claim 10, wherein the adhesion layer portion comprises a polymer glue.

17. The solar cell of claim 10, wherein the diffusion region is an N-type diffusion region, and the adhesion layer portion comprises P-type silicon.

18. The solar cell of claim 10, wherein the conductive layer has a thickness of approximately 2-10 microns, and wherein the conductive contact is a back contact of the solar cell comprising the conductive layer, an electroless plated nickel (Ni) layer disposed on the conductive layer, and an electroplated copper (Cu) layer disposed on the Ni layer.

19. A method of fabricating a solar cell, the method comprising:

forming an adhesion layer above an emitter region of a substrate;

forming a metal seed paste layer on the adhesion layer, the metal seed paste layer including silicon;

annealing the metal seed paste layer and the adhesion layer to form a conductive layer in contact with the emitter region of the substrate, wherein the adhesion layer mixes with the silicon in the metal seed paste layer so as to adhere the conductive layer to the emitter region of the substrate; and

forming a conductive contact for the solar cell from the conductive layer.

~~20. The method of claim 19, wherein annealing the metal seed paste layer and the adhesion layer comprises mixing the metal seed paste layer and the adhesion layer to form the conductive layer.~~