Dopant Ink Composition and Method of Fabricating a Solar Cell There From

[0001] The invention described herein was made with Governmental support under contract number DE-FC36-07GO17043 awarded by the United States Department of Energy. The Government may have certain rights in the invention.

TECHNICAL FIELD

[0002] Embodiments of the present invention are in the field of renewable energy and, in particular, dopant ink compositions and methods of fabricating solar cells there from.

BACKGROUND

[0003] Photovoltaic cells, commonly known as solar cells, are well known devices for direct conversion of solar radiation into electrical energy. Generally, solar cells are fabricated on a semiconductor wafer or substrate using semiconductor processing techniques to form a p-n junction near a surface of the substrate. Solar radiation impinging on the surface of, and entering into, the substrate creates electron and hole pairs in the bulk of the substrate. The electron and hole pairs migrate to p-doped and n-doped regions in the substrate, thereby generating a voltage differential between the doped regions. The doped regions are connected to conductive regions on the solar cell to direct an electrical current from the cell to an external circuit coupled thereto.

[0004] Efficiency is an important characteristic of a solar cell as it is directly related to the capability of the solar cell to generate power. Likewise, efficiency in producing solar cells is directly related to the cost effectiveness of such solar cells. Accordingly, techniques for increasing the efficiency of solar cells, or techniques for increasing the efficiency in the manufacture of solar cells, are generally desirable. Embodiments of the present invention allow for increased solar cell manufacture efficiency by providing novel processes for fabricating solar cell structures.

SUMMARY

[0004a] According to a first aspect, there is provided a dopant ink composition, comprising:
a cross-linkable matrix precursor; a plurality of particles; a bound dopant species that is bound to a surface of one of the particles through a chemical bond; and a solvent.

[0004b] According to a second aspect, there is provided a method of fabricating a solar cell, the method comprising: delivering a dopant ink composition to a region above a substrate, the dopant ink composition comprising a cross-linkable matrix precursor, a bound dopant species, and a solvent; baking the dopant ink composition to remove a substantial portion of the solvent of the dopant ink composition; curing the baked dopant ink composition to cross-link a substantial portion of the cross-linkable matrix precursor of the dopant ink composition; and driving dopants from the cured dopant ink composition toward the substrate, wherein the dopant ink composition further comprises a plurality of particles, and wherein the bound dopant species is bound to a surface of one of the particles through a chemical bond.

[0004d] According to a third aspect, there is provided a solar cell fabricated according to the second aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1A is a schematic diagram of a dopant ink composition, in accordance with an embodiment of the present invention.

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SUMMARY

[0004a] According to a first aspect, there is provided a dopant ink composition, comprising: a cross-linkable matrix precursor; a bound dopant species; and a solvent.

[0004b] According to a second aspect, there is provided a dopant ink composition, comprising: a cross-linkable matrix precursor; a plurality of particles; a dopant species coupled to one of the particles; and a solvent.

[0004c] According to a third aspect, there is provided a method of fabricating a solar cell, the method comprising: delivering a dopant ink composition to a region above a substrate, the dopant ink composition comprising a cross-linkable matrix precursor, a bound dopant species, and a solvent; baking the dopant ink composition to remove a substantial portion of the solvent of the dopant ink composition; curing the baked dopant ink composition to cross-link a substantial portion of the cross-linkable matrix precursor of the dopant ink composition; and driving dopants from the cured dopant ink composition toward the substrate.

[0004d] According to a fourth aspect, there is provided a solar cell fabricated according to the third aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1A is a schematic diagram of a dopant ink composition, in accordance with an embodiment of the present invention.

CLAIMS

What is claimed is:

1. A dopant ink composition, comprising:
   a cross-linkable matrix precursor;
   a plurality of particles;
   a bound dopant species that is bound to a surface of one of the particles through a chemical bond; and
   a solvent.

2. The dopant ink composition of claim 1, wherein the bound dopant species is bound to the cross-linkable matrix precursor.

3. The dopant ink composition of claim 2, wherein the bound dopant species is an n-type dopant precursor bound to the cross-linkable matrix precursor through a chemical bond, the n-type dopant precursor selected from the group consisting of a phosphine moiety and an organophosphine moiety.

4. The dopant ink composition of claim 2, wherein the bound dopant species is a p-type dopant precursor bound to the cross-linkable matrix precursor through a chemical bond, the p-type dopant precursor selected from the group consisting of a borane moiety and an organoborane moiety.

~~5. The dopant ink composition of claim 1, further comprising:~~
   ~~a plurality of particles, wherein the bound dopant species is bound to one or more of the particles.~~

~~6. The dopant ink composition of claim 5, wherein the bound dopant species is an n-type or a p-type dopant atom incorporated into one of the particles.~~

~~75~~. The dopant ink composition of claim ~~51~~, wherein the bound dopant species is an n-type or a p-type dopant precursor ~~bound to a surface of one of the particles through a chemical bond~~.

~~86~~. The dopant ink composition of claim 1, wherein the cross-linkable matrix precursor is selected from the group consisting of a siloxane species, a silane species, and a cyclosilane species.

97. The dopant ink composition of claim 1, wherein the solvent is selected from the group consisting of an alkyl-based alcohol, an aryl-based alcohol, decalin, an alkane, an aromatic, an ethyl acetate species, and water.

~~10. A dopant ink composition, comprising:~~

~~a cross-linkable matrix precursor;~~

~~a plurality of particles;~~

~~a dopant species coupled to one of the particles; and~~

~~a solvent.~~

~~11. The dopant ink composition of claim 10, wherein the dopant species is an n-type or a p-type dopant atom incorporated into the particle.~~

~~12. The dopant ink composition of claim 10, wherein the dopant species is an n-type or a p-type dopant precursor tethered to a surface of the particle through a chemical bond.~~

~~13. The dopant ink composition of claim 10, wherein the solvent is selected from the group consisting of an alkyl-based alcohol, an aryl-based alcohol, decalin, an alkane, an aromatic, an ethyl acetate species, and water, and wherein the cross-linkable matrix precursor is dissolved in the solvent.~~

~~14~~8. A method of fabricating a solar cell, the method comprising:

delivering a dopant ink composition to a region above a substrate, the dopant ink composition comprising a cross-linkable matrix precursor, a bound dopant species, and a solvent;

baking the dopant ink composition to remove a substantial portion of the solvent of the dopant ink composition;

curing the baked dopant ink composition to cross-link a substantial portion of the cross-linkable matrix precursor of the dopant ink composition; and

driving dopants from the cured dopant ink composition toward the substrate, wherein the dopant ink composition further comprises a plurality of particles, and wherein the bound dopant species is bound to a surface of one of the particles through a chemical bond.

~~15. The method of claim 14, wherein the dopant ink composition further comprises a plurality of particles, and wherein the bound dopant species is coupled to one of the particles.~~

~~16~~9. The method of claim ~~14~~8, wherein delivering the dopant ink composition comprises using a fluid deposition technique selected from the group consisting of ink jetting, screen printing, blading, transferring by pipette, spin coating and etching, gravure printing, and slot-die coating.

~~17~~10. The method of claim ~~14~~8, wherein baking the dopant ink composition comprises heating to a temperature approximately in the range of 100 – 400 degrees Celsius, curing the baked dopant ink composition comprises heating to a temperature approximately in the range of 350 – 900 degrees Celsius, and driving dopants from the cured dopant ink composition comprises heating to a temperature approximately in the range of 850 – 1050 degrees Celsius.

~~18~~11. The method of claim ~~14~~8, wherein the baking and the curing are performed in the same process operation.

~~19~~12. The method of claim ~~14~~8, wherein the dopant ink composition is a first dopant ink composition for a first conductivity type, the method further comprising:

prior to baking the first dopant ink composition, delivering a second dopant ink composition for a second, different, conductivity type to a second region above the substrate.

~~20~~13. The method of claim ~~19~~12, wherein the first dopant ink composition and the second dopant ink composition are delivered sequentially.

~~21~~14. The method of claim ~~19~~12, wherein the first dopant ink composition and the second dopant ink composition are delivered substantially simultaneously.

~~22~~15. The method of claim ~~14~~8, wherein the dopant ink composition is a first dopant ink composition for a first conductivity type, the method further comprising:

subsequent to baking but prior to curing the first dopant ink composition, delivering a second dopant ink composition for a second, different, conductivity type to a second region above the substrate.

~~23~~16. The method of claim ~~1~~48, wherein the dopant ink composition is a first dopant ink composition for a first conductivity type, the method further comprising:

subsequent to baking and curing but prior to driving dopants from the first dopant ink composition, delivering a second dopant ink composition for a second, different, conductivity type to a second region above the substrate.

~~24~~17. The method of claim ~~1~~48, wherein the region is an upper surface of the substrate, and driving dopants from the cured dopant ink composition toward the substrate comprises driving dopants into the substrate.

~~25~~18. The method of claim ~~1~~48, wherein the region is an upper surface of a semiconductor layer disposed above the substrate, and driving dopants from the cured dopant ink composition toward the substrate comprises driving dopants into the semiconductor layer.

~~26~~19. A solar cell fabricated according to the method of claim ~~1~~48.