METHOD FOR FORMING DIFFUSION REGIONS IN A SILICON SUBSTRATE

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0001] The United States government has a paid-up license in this invention and the right in limited circumstances to require the patent owner to license others on reasonable terms as provided by the terms of DE-FC36-07GO17043 awarded by the DOE.

TECHNICAL FIELD

[0002] Embodiments of the subject matter described herein relate generally to solar cell manufacture. More particularly, embodiments of the subject matter relate to thin silicon solar cells and techniques for manufacture.

BACKGROUND

[0003] Solar cells are well known devices for converting solar radiation to electrical energy. They may be fabricated on a semiconductor wafer using semiconductor processing technology. A solar cell includes P-type and N-type diffusion regions. Solar radiation impinging on the solar cell creates electrons and holes that migrate to the diffusion regions, thereby creating voltage differentials between the diffusion regions. In a backside contact solar cell, both the diffusion regions and the metal contact fingers coupled to them are on the backside of the solar cell. The contact fingers allow an external electrical circuit to be coupled to and be powered by the solar cell.

[0004] Accordingly, techniques for improving the fabrication process and reducing the cost of manufacturing solar cells are generally desirable. Such techniques include printing and curing of dopants on silicon substrates through processes like ink-jet printing. These or other similar embodiments form the background of the current invention.

SUMMARY

[0004a] According to a first aspect, there is provided a method of manufacturing solar cells, the method comprising: depositing an etch-resistant dopant material on a silicon substrate, the etch-resistant dopant material comprising a dopant source;

forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material; and heating the silicon substrate and the etch-resistant dopant material to a temperature sufficient to cause the dopant source to diffuse into the silicon substrate.

[0004b] According to a second aspect, there is provided a method of manufacturing solar cells, the method comprising: depositing a dopant material on a silicon substrate having a photovoltaic solar cell structure; forming a cross-linked matrix in the dopant material using a non-thermal exposure of the dopant material to ultraviolet light through a photo-polymerization process; and heating the silicon substrate of the dopant material to a temperature sufficient to cause the dopant source to diffuse into the silicon substrate.

[0004c] According to a third aspect, there is provided a solar cell fabricated in accordance to the second aspect.

[0004d] According to a fourth aspect, there is provided a method of manufacturing solar cells, the method comprising: forming a thin dielectric layer on a surface of a silicon substrate; forming a polysilicon layer over the thin dielectric layer; depositing an etch-resistant dopant material comprising a dopant source material on the polysilicon layer; forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material; and heating the etch-resistant dopant material to a temperature wherein the dopant source material diffuses into the polysilicon layer.

[0004e] According to a fifth aspect, there is provided a solar cell fabricated in accordance to the fourth aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A more complete understanding of the subject matter may be derived by referring to the detailed description and claims when considered in conjunction with

CLAIMS

What is claimed is:

1) A method of manufacturing solar cells, the method comprising:

depositing an etch-resistant dopant material on a silicon substrate, the etch-resistant dopant material comprising a dopant source;

forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material; and

heating the silicon substrate and the etch-resistant dopant material to a temperature sufficient to cause the dopant source to diffuse into the silicon substrate.

2) The method of Claim 1, wherein forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material comprises causing a phase change from liquid to solid of the etch-resistant dopant material on the silicon substrate.

3) The method of Claim 1, wherein forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material comprises exposing the etch-resistant dopant material to non-infrared electromagnetic radiation.

4) The method of Claim 3, wherein exposing the etch-resistant dopant material to non-infrared electromagnetic radiation comprises exposing the etch-resistant dopant material to ultraviolet light.

5) The method of Claim 3, wherein exposing the etch-resistant dopant material to non-infrared electromagnetic radiation comprises exposing the etch-resistant dopant material with light from the visible spectrum or electromagnetic radiation having a wavelength of 380 to 760 nanometers.

6) The method of Claim 1, wherein forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant

material comprises transmitting acoustic waves toward the etch-resistant dopant material.

7) The method of Claim 1, wherein depositing the etch-resistant dopant material comprises dispensing the etch-resistant dopant in liquid form on the silicon substrate.

8) The method of Claim 7, wherein dispensing the etch-resistant dopant material comprises screen printing the etch-resistant dopant material onto a silicon substrate.

9) The method of Claim 7, wherein dispensing the etch-resistant dopant material comprises ink-jet printing the etch-resistant dopant material onto a silicon substrate.

10) The method of Claim 7, wherein dispensing the etch-resistant dopant material comprises spin coating the etch-resistant dopant material onto a silicon substrate.

11) The method of Claim 1, wherein dispensing the etch-resistant dopant material comprising a dopant source onto the silicon substrate comprises dispensing a dopant material comprising a single-polarity dopant source onto the silicon substrate.

12) The method of Claim 11, wherein dispensing a dopant material comprising a single-polarity dopant source onto the silicon substrate comprises dispensing a positive-type dopant onto the silicon substrate.

13) The method of Claim 11, wherein dispensing a dopant material comprising a single-polarity dopant source onto the silicon substrate comprises dispensing a negative-type dopant onto the silicon substrate.

14) The method of Claim 1, further comprising selectively etching the silicon substrate to remove the dopant source material without etching the silicon substrate.

15) The method of Claim 1, further comprising the step of reducing the amount of solvent in the etch-resistant dopant material by heating the etch-resistant dopant material to at least 400° Celsius after forming the cross-linked matrix in the etch-resistant dopant material.

16) A solar cell fabricated in accordance to the method of Claim 1.

17) A method of manufacturing solar cells, the method comprising:

depositing a dopant material on a silicon substrate having a photovoltaic solar cell structure;

forming a cross-linked matrix in the dopant material using a non-thermal exposure of the dopant material to ultraviolet light through a photo-polymerization process; and

heating the silicon substrate of the dopant material to a temperature sufficient to cause the dopant source to diffuse into the silicon substrate.

18) The method of Claim 17, wherein forming a cross-linked matrix in the dopant material using a non-thermal exposure of the dopant material to ultraviolet light comprises exposing the dopant material to electromagnetic radiation having a wavelength of 8 to 400 nanometers.

19) The method of Claim 17, wherein forming a cross-linked matrix in the dopant material using a non-thermal exposure of the dopant material to ultraviolet light comprises exposing the dopant material to ultraviolet light forming a phase change from liquid to solid of the dopant material during the photo-polymerization process.

20) The method of Claim 17, wherein forming a cross-linked matrix in the dopant material using a non-thermal exposure of the dopant material to ultraviolet light comprises exposing the dopant material to perform a curing step selected from the group comprising acrylate polymerization, cationic polymerization, thiolene chemical application and hydrosilane addition.

21) The method of Claim 17, wherein depositing the dopant material comprises depositing a chemical group comprising a chemical structure selected from the group comprising silanes, cyclosilanes, and siloxanes.

22) The method of Claim 17, further comprising the step of etching the silicon substrate using the dopant material as an etch-mask after forming the cross-linked matrix in the dopant material.

23) The method of Claim 22, wherein etching the silicon substrate comprises etching at least part of the photovoltaic solar cell structure of the silicon substrate.

24) A solar cell fabricated in accordance to the method of Claim 17.

25) A method of manufacturing solar cells, the method comprising:

forming a thin dielectric layer on a surface of a silicon substrate;

forming a polysilicon layer over the thin dielectric layer;

depositing an etch-resistant dopant material comprising a dopant source material on the polysilicon layer;

forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material; and

heating the etch-resistant dopant material to a temperature wherein the dopant source material diffuses into the polysilicon layer.

26) The method of Claim 25, further comprising the step of etching the polysilicon layer using the etch-resistant dopant material as an etch-mask.

27) The method of Claim 25, wherein depositing the etch-resistant dopant material comprises dispensing the etch-resistant dopant material in a plurality of interdigitated contact fingers on the silicon substrate.

28) A solar cell fabricated in accordance to the method of Claim 25.

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[0004] Accordingly, techniques for improving the fabrication process and reducing the cost of manufacturing solar cells are generally desirable. Such techniques include printing and curing of dopants on silicon substrates through processes like ink-jet printing. These or other similar embodiments form the background of the current invention.

SUMMARY

[0004a] According to a first aspect, there is provided a method of manufacturing solar cells, the method comprising: depositing, in a liquid phase, an etch-resistant dopant material on a silicon substrate, the etch-resistant dopant material comprising a

dopant source and a solvent; forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material, the cross-linked matrix having a structure, and the non-thermal cure causing a phase change of the etch-resistant dopant material from liquid to solid; subsequently, removing the solvent from the etch-resistant dopant material without altering the structure of the cross-linked matrix; and heating the silicon substrate and the etch-resistant dopant material having the cross-linked matrix to a temperature sufficient to cause the dopant source to diffuse into the silicon substrate.

[0004b] According to a second aspect, there is provided a method of manufacturing solar cells, the method comprising: depositing, in a liquid phase, a dopant material on a silicon substrate having a photovoltaic solar cell structure, the dopant material comprising a dopant and a solvent; forming a cross-linked matrix in the dopant material using a non-thermal exposure of the dopant material to ultraviolet light through a photo-polymerization process, the cross-linked matrix having a structure, and the photo-polymerization process causing a phase change of the dopant material from liquid to solid; subsequently, removing the solvent from the dopant material without altering the structure of the cross-linked matrix; and heating the silicon substrate and the dopant material having the cross-linked matrix to a temperature sufficient to cause the dopant to diffuse into the silicon substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A more complete understanding of the subject matter may be derived by referring to the detailed description and claims when considered in conjunction with

What is claimed is:

1. A method of manufacturing solar cells, the method comprising:

depositing, in a liquid phase, an etch-resistant dopant material on a silicon substrate, the etch-resistant dopant material comprising a dopant source and a solvent;

forming a cross-linked matrix in the etch-resistant dopant material using a non-thermal cure of the etch-resistant dopant material, the cross-linked matrix having a structure, and the non-thermal cure causing a phase change of the etch-resistant dopant material from liquid to solid; subsequently,

removing the solvent from the etch-resistant dopant material without altering the structure of the cross-linked matrix; and

heating the silicon substrate and the etch-resistant dopant material having the cross-linked matrix to a temperature sufficient to cause the dopant source to diffuse into the silicon substrate.

2. The method of claim 1, wherein forming the cross-linked matrix in the etch-resistant dopant material using the non-thermal cure of the etch-resistant dopant material comprises exposing the etch-resistant dopant material to non-infrared electromagnetic radiation.

3. The method of claim 2, wherein exposing the etch-resistant dopant material to the non-infrared electromagnetic radiation comprises exposing the etch-resistant dopant material to ultraviolet light.

4. The method of claim 2, wherein exposing the etch-resistant dopant material to the non-infrared electromagnetic radiation comprises exposing the etch-resistant dopant material with light from the visible spectrum or electromagnetic radiation having a wavelength of 380 to 760 nanometers.

5. The method of claim 1, wherein forming the cross-linked matrix in the etch-resistant dopant material using the non-thermal cure of the etch-resistant dopant material comprises transmitting acoustic waves toward the etch-resistant dopant material.

6. The method of claim 1, wherein depositing the etch-resistant dopant material comprises dispensing the etch-resistant dopant on the silicon substrate.

7. The method of claim 6, wherein dispensing the etch-resistant dopant material comprises screen printing the etch-resistant dopant material onto the silicon substrate.

8. The method of claim 6, wherein dispensing the etch-resistant dopant material comprises ink-jet printing the etch-resistant dopant material onto the silicon substrate.

9. The method of claim 6, wherein dispensing the etch-resistant dopant material comprises spin coating the etch-resistant dopant material onto the silicon substrate.

10. The method of claim 6, wherein dispensing the etch-resistant dopant material comprising the dopant source onto the silicon substrate comprises dispensing a dopant material comprising a single-polarity dopant source onto the silicon substrate.

11. The method of claim 10, wherein dispensing the dopant material comprising the single-polarity dopant source onto the silicon substrate comprises dispensing a positive-type dopant onto the silicon substrate.

12. The method of claim 10, wherein dispensing the dopant material comprising the single-polarity dopant source onto the silicon substrate comprises dispensing a negative-type dopant onto the silicon substrate.

13. The method of claim 1, further comprising selectively etching the silicon substrate to remove the etch-resistant dopant material without etching the silicon substrate.

14. The method of claim 1, removing the solvent from the etch-resistant dopant material comprises heating the etch-resistant dopant material to at least 400° Celsius.

15. A method of manufacturing solar cells, the method comprising:

depositing, in a liquid phase, a dopant material on a silicon substrate having a photovoltaic solar cell structure, the dopant material comprising a dopant and a solvent;

forming a cross-linked matrix in the dopant material using a non-thermal exposure of the dopant material to ultraviolet light through a photo-polymerization process, the cross-linked matrix having a structure, and the photo-polymerization process causing a phase change of the dopant material from liquid to solid; subsequently,

removing the solvent from the dopant material without altering the structure of the cross-linked matrix; and

heating the silicon substrate and the dopant material having the cross-linked matrix to a temperature sufficient to cause the dopant to diffuse into the silicon substrate.

16. The method of claim 15, wherein forming the cross-linked matrix in the dopant material using the non-thermal exposure of the dopant material to the ultraviolet light comprises exposing the dopant material to electromagnetic radiation having a wavelength of 8 to 400 nanometers.

17. The method of claim 15, wherein forming the cross-linked matrix in the dopant material using the non-thermal exposure of the dopant material to the ultraviolet light comprises exposing the dopant material to perform a curing step selected from the group comprising acrylate polymerization, cationic polymerization, thiolene chemical application and hydrosilane addition.

18. The method of claim 15, wherein depositing the dopant material comprises depositing a chemical group comprising a chemical structure selected from the group comprising silanes, cyclosilanes, and siloxanes.

19. The method of claim 15, further comprising the step of etching the silicon substrate using the dopant material as an etch-mask after forming the cross-linked matrix in the dopant material.

20. The method of claim 19, wherein etching the silicon substrate comprises etching at least part of the photovoltaic solar cell structure of the silicon substrate.