SUMMARY

[0011] According to an aspect of the present invention, there is provided a photovoltaic cell comprising:

a copper-based current collector located on a semiconductor substrate, the copper-based current collector comprising:

an electrically conductive diffusion barrier disposed directly on the semiconductor substrate, the electrically conductive diffusion barrier limiting the passage of copper therethrough and being selected from the group consisting of a metal nitride, a metal carbide, a metal boride, a metal tungstide, and any combination thereof; and

a copper contact disposed on the electrically conductive diffusion barrier, the copper contact being formed from copper nanoparticles that have been at least partially fused together;

wherein the semiconductor substrate comprises an n-doped region and a p-doped region, and the semiconductor substrate is configured for receipt of electromagnetic radiation and generation of an electrical current therefrom.

[0012] According to another aspect of the present invention, there is provided a method for forming a photovoltaic cell, the method comprising:

applying an electrically conductive diffusion barrier directly onto a semiconductor substrate comprising an n-doped region and a p-doped region, the electrically conductive diffusion barrier limiting the passage of copper therethrough and being selected from the group consisting of a metal nitride, a metal carbide, a metal boride, a metal tungstide, and any combination thereof;

applying copper nanoparticles onto the electrically conductive diffusion barrier; and

heating the copper nanoparticles to a temperature sufficient to at least partially fuse the copper nanoparticles together, thereby forming a copper contact on the electrically conductive diffusion barrier.

[0013] The foregoing has outlined rather broadly the features of the present disclosure in order that the detailed description that follows can be better understood. Additional features and advantages of the disclosure will be described hereinafter, which form the subject of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions to be taken in conjunction with the accompanying drawings describing specific embodiments of the disclosure, wherein:

CLAIMS

What is claimed is the following:

1. A photovoltaic cell comprising:

a copper-based current collector located on a semiconductor substrate, the copper-based current collector comprising:

an electrically conductive diffusion barrier disposed on the semiconductor substrate, the electrically conductive diffusion barrier limiting the passage of copper therethrough; and

a copper contact disposed on the electrically conductive diffusion barrier, the copper contact being formed from copper nanoparticles that have been at least partially fused together;

wherein the semiconductor substrate comprises an n-doped region and a p-doped region, and the semiconductor substrate is configured for receipt of electromagnetic radiation and generation of an electrical current therefrom.

2. The photovoltaic cell of claim 1, wherein the copper-based current collector is located on a face of the photovoltaic cell that receives the electromagnetic radiation.

3. The photovoltaic cell of claim 1, wherein the copper-based current collector is located on a face of the photovoltaic cell opposite a face of the photovoltaic cell that receives the electromagnetic radiation.

4. The photovoltaic cell of claim 1, wherein the copper-based current collector is in contact with the n-doped region of the semiconductor substrate.

5. The photovoltaic cell of claim 4, further comprising:

an electrical connection in contact with the p-doped region of the semiconductor substrate.

6. The photovoltaic cell of claim 1, wherein the semiconductor substrate comprises a silicon substrate.

7. The photovoltaic cell of claim 6, wherein the electrically conductive diffusion barrier is selected from the group consisting of TiN, TaN, WN, TiW, W and any combination thereof.

8. The photovoltaic cell of claim 7, wherein the electrically conductive diffusion barrier is formed from nanoparticles that have been at least partially fused together.

9. The photovoltaic cell of claim 1, wherein the copper contact further comprises a corrosion-resistant substance.

10. The photovoltaic cell of claim 9, wherein a corrosion-resistant coating is disposed on the copper contact, the corrosion-resistant coating being selected from the group consisting of a Sn coating, an Ag coating, a SnAgCu coating, an Al coating, a Si coating, a polymer coating, and any combination thereof.

11. The photovoltaic cell of claim 1, wherein the copper nanoparticles are mixed with micron-scale copper particles while being formed into the copper contact.

12. The photovoltaic cell of claim 1, wherein the copper contact further comprises a conductive additive selected from the group consisting of carbon black, pyrene, phenanthrene, carbon nanotubes, graphene, and any combination thereof.

13. The photovoltaic cell of claim 12, wherein the conductive additive is mixed with the copper nanoparticles while being formed into the copper contact.

14. The photovoltaic cell of claim 12, wherein the conductive additive is disposed on the copper contact.

15. The photovoltaic cell of claim 1, further comprising:

an antireflective coating disposed on a face of the semiconductor substrate that receives the electromagnetic radiation.

16. A method for forming a photovoltaic cell, the method comprising:

applying an electrically conductive diffusion barrier onto a semiconductor substrate comprising an n-doped region and a p-doped region, the electrically conductive diffusion barrier limiting the passage of copper

therethrough;

applying copper nanoparticles onto the electrically conductive diffusion barrier; and

heating the copper nanoparticles to a temperature sufficient to at least partially fuse the copper nanoparticles together, thereby forming a copper contact on the electrically conductive diffusion barrier.

17. The method of claim 16, wherein the electrically conductive diffusion barrier and the copper contact are disposed on the n-doped region of the semiconductor substrate.

18. The method of claim 16, wherein the copper nanoparticles are applied to the electrically conductive diffusion barrier as a dispensible nanoparticle paste formulation comprising an organic matrix in which the copper nanoparticles are dispersed.

19. The method of claim 18, wherein at least a portion of the copper nanoparticles are about 20 nm in size or smaller.

20. The method of claim 18, wherein the dispensible nanoparticle paste formulation further comprises micron-scale copper particles, a conductive additive, a corrosion-resistant substance, or any combination thereof.

21. The method of claim 16, wherein the semiconductor substrate comprises a silicon substrate.

22. The method of claim 21, wherein the electrically conductive diffusion barrier is selected from the group consisting of TiN, TaN, WN, TiW, W and any combination thereof.

23. The method of claim 22, wherein the electrically conductive diffusion barrier is applied to the semiconductor substrate by plating, physical vapor deposition, or chemical vapor deposition.

24. The method of claim 22, further comprising:

applying a plurality of nanoparticles to the semiconductor substrate; and

at least partially fusing the nanoparticles together to form the electrically conductive diffusion barrier.

25. The method of claim 16, further comprising:

adhering the semiconductor substrate to a surface while at least partially fusing the copper nanoparticles together.

Claims

1. A photovoltaic cell comprising:

a copper-based current collector located on a semiconductor substrate, the copper-based current collector comprising:

an electrically conductive diffusion barrier disposed directly on the semiconductor substrate, the electrically conductive diffusion barrier limiting the passage of copper therethrough and being selected from the group consisting of a metal nitride, a metal carbide, a metal boride, a metal tungstide, and any combination thereof; and

a copper contact disposed on the electrically conductive diffusion barrier, the copper contact being formed from copper nanoparticles that have been at least partially fused together;

wherein the semiconductor substrate comprises an n-doped region and a p-doped region, and the semiconductor substrate is configured for receipt of electromagnetic radiation and generation of an electrical current therefrom.

2. The photovoltaic cell of claim 1, wherein the copper-based current collector is located on a face of the photovoltaic cell that receives the electromagnetic radiation.

3. The photovoltaic cell of claim 1, wherein the copper-based current collector is located on a face of the photovoltaic cell opposite a face of the photovoltaic cell that receives the electromagnetic radiation.

4. The photovoltaic cell of claim 1, wherein the copper-based current collector is in contact with the n-doped region of the semiconductor substrate.

5. The photovoltaic cell of claim 4, further comprising:

an electrical connection in contact with the p-doped region of the semiconductor substrate.

6. The photovoltaic cell of claim 1, wherein the semiconductor substrate comprises a silicon substrate.

7. The photovoltaic cell of claim 6, wherein the electrically conductive diffusion barrier is selected from the group consisting of TiN, TaN, WN, TiW and any combination thereof.

8. The photovoltaic cell of claim 7, wherein the electrically conductive diffusion barrier is formed from nanoparticles that have been at least partially fused together.

9. The photovoltaic cell of claim 1, wherein the copper contact further comprises a corrosion-resistant substance.

10. The photovoltaic cell of claim 9, wherein a corrosion-resistant coating is disposed on the copper contact, the corrosion-resistant coating being selected from the group consisting of a Sn coating, an Ag coating, a SnAgCu coating, an Al coating, a Si coating, a polymer coating, and any combination thereof.

11. The photovoltaic cell of claim 1, wherein the copper nanoparticles are mixed with micron-scale copper particles while being formed into the copper contact.

12. The photovoltaic cell of claim 1, wherein the copper contact further comprises a conductive additive selected from the group consisting of carbon black, pyrene, phenanthrene, carbon nanotubes, graphene, and any combination thereof.

13. The photovoltaic cell of claim 12, wherein the conductive additive is mixed with the copper nanoparticles while being formed into the copper contact.

14. (Currently Amended) The photovoltaic cell of claim 12, wherein the conductive additive is disposed on the copper contact after its formation.

15. The photovoltaic cell of claim 1, further comprising:

an antireflective coating disposed on a face of the semiconductor substrate that receives the electromagnetic radiation.

16. A method for forming a photovoltaic cell, the method comprising:

applying an electrically conductive diffusion barrier directly onto a semiconductor substrate comprising an n-doped region and a p-doped region, the electrically conductive diffusion barrier limiting the passage of copper therethrough and being selected from the

group consisting of a metal nitride, a metal carbide, a metal boride, a metal tungstide, and any combination thereof;

applying copper nanoparticles onto the electrically conductive diffusion barrier; and

heating the copper nanoparticles to a temperature sufficient to at least partially fuse the copper nanoparticles together, thereby forming a copper contact on the electrically conductive diffusion barrier.

17. The method of claim 16, wherein the electrically conductive diffusion barrier and the copper contact are disposed on the n-doped region of the semiconductor substrate.

18. The method of claim 16, wherein the copper nanoparticles are applied to the electrically conductive diffusion barrier as a dispensible nanoparticle paste formulation comprising an organic matrix in which the copper nanoparticles are dispersed.

19. The method of claim 18, wherein at least a portion of the copper nanoparticles are about 20 nm in size or smaller.

20. The method of claim 18, wherein the dispensible nanoparticle paste formulation further comprises micron-scale copper particles, a conductive additive, a corrosion-resistant substance, or any combination thereof.

21. The method of claim 16, wherein the semiconductor substrate comprises a silicon substrate.

22. The method of claim 21, wherein the electrically conductive diffusion barrier is selected from the group consisting of TiN, TaN, WN, TiW and any combination thereof.

23. The method of claim 22, wherein the electrically conductive diffusion barrier is directly applied to the semiconductor substrate by plating, physical vapor deposition, or chemical vapor deposition.

24. The method of claim 22, further comprising:

directly applying a plurality of nanoparticles to the semiconductor substrate; and

at least partially fusing the nanoparticles together to form the electrically conductive diffusion barrier.

25. The method of claim 16, further comprising:

adhering the semiconductor substrate to a surface while at least partially fusing the copper nanoparticles together.