CLAIMS

WHAT IS CLAIMED IS:

1. A method, comprising:
    (a) providing a silicon solar module with a first voltage output, wherein the silicon solar module comprises a top glass panel;
    (b) forming a perovskite layer on said top glass panel;
    (c) fabricating one or more perovskite solar cells from said perovskite layer, wherein said one or more perovskite solar cells produce a voltage substantially matched to said voltage output of said silicon solar module; and
    (d) electrically connecting said silicon solar module to said one or more perovskite solar cells.
2. The method of claim 1, wherein said fabricating comprises use of a laser scribe to define said one or more perovskite solar cells.
3. The method of claim 1, wherein said one or more perovskite solar cells are a plurality of perovskite solar cells.
4. The method of claim 3, wherein said plurality of perovskite solar cells are connected in series.
5. The method of claim 1, further comprising applying a plurality of contacts to said one or more perovskite solar cells to electrically couple said one or more perovskite solar cells.
6. The method of claim 1, further comprising applying an encapsulant to said one or more perovskite solar cells.
7. The method of claim 6, wherein said encapsulant is a thermal-plastic polyolefin.
8. The method of claim 7, wherein said encapsulant is ethyl-vinyl acetate.
9. The method of claim 1, further comprising applying an edge seal to said one or more perovskite solar cells.
10. A tandem solar module, comprising:

    a silicon solar panel comprising (i) a plurality of silicon solar cells connected in series and (ii) a top glass sheet, wherein said plurality of silicon solar cells are connected in series and combined have a first open circuit voltage;

    a perovskite solar panel disposed on an underside of said top glass sheet of said silicon solar panel, wherein said perovskite solar panel comprises a plurality of segments, wherein each segment of said plurality of segments comprises a plurality of laser-scribed strips of perovskite, wherein said plurality of laser-scribed strips of perovskite within a

segment are connected in series to generate a second open circuit voltage that is substantially the same as said first open circuit voltage; and

an interconnect connecting said plurality of silicon solar cells and said plurality of segments of said perovskite solar panel in parallel.

11. The device of claim 10, wherein said plurality of segments comprises from about 10 to about 200 segments.
12. The device of claim 10, wherein said silicon solar panel is a top contact solar panel, an integrated back contact solar panel, or a shingled solar panel.
13. The device of claim 10, wherein said silicon solar panel and said perovskite solar panel are connected to a same junction box.
14. The device of claim 10, wherein said silicon solar panel and said perovskite solar panel have a substantially similar area.
15. The device of claim 10, wherein said plurality of laser-scribed strips of perovskite are connected via a P1/P2/P3 scheme.

~~16. A perovskite layer, comprising:~~

~~a composition of $MA_{n1}FA_{n2}Cs_{n3}PbX_3$, wherein MA is methylammonium, FA is formamidinium, n1, n2, and n3 are independently greater than 0 and less than 1, and n1 + n2 + n3 = 1, wherein a perovskite solar cell comprising said perovskite layer retains at least about 80% solar conversion efficiency after 300 hours of illumination under one sun conditions in an air atmosphere at >25 °C and <100 °C.~~

~~17. The perovskite layer of claim 16, wherein X is selected from the group consisting of fluorine, chlorine, bromine, and iodine.~~

~~18. The perovskite layer of claim 17, wherein X is a combination of two or more of fluorine, chlorine, bromine, and iodine.~~

~~19. The perovskite layer of claim 16, wherein n1 is from about 0.001 to about 0.05.~~

~~20. The perovskite layer of claim 16, wherein n3 is from about 0.001 to about 0.15.~~

~~21. The perovskite layer of claim 16, wherein said solar conversion efficiency is at least about 90% of the initial conversion efficiency value after 300 hours of illumination under one sun conditions.~~

~~22. The perovskite layer of claim 21, wherein said solar conversion efficiency is at least about 95% of the initial conversion efficiency value after 300 hours of illumination under one sun conditions.~~

23. The perovskite layer of claim 16, wherein said perovskite layer does not comprise additional additives.

24. A method, comprising:

(a) providing a substrate;

(b) applying a perovskite precursor to said substrate;

(c) annealing said perovskite precursor to form a perovskite layer; wherein said perovskite layer has a composition of $MA_{n1}FA_{n2}Cs_{n3}PbX_3$, wherein n1, n2, and n3 are independently greater than 0 and less than 1 and n1 + n2 + n3 = 1,wherein a perovskite solar cell comprising said perovskite layer retains at least about 80% solar conversion efficiency after 300 hours of illumination under one sun conditions at >25 °C and <100 °C; and

(d) subjecting said perovskite layer to an encapsulation lamination process at a temperature of at least about 120 °C.

25. The method of claim 24, wherein said perovskite solar cell retains at least about 80% of the initial conversion efficiency value after said encapsulation lamination process.

26. The method of claim 25, wherein said perovskite solar cell retains at least about 97% of the initial conversion efficiency value after said encapsulation lamination process.

27. The method of claim 24, wherein said applying said perovskite precursor via an ultrasonic spray-on process.

28. The method of claim 24, wherein said annealing process comprises heating said perovskite layer to a temperature of at least about 40—120 °C.

29. A perovskite layer, comprising:

a composition of $MA_{n1}FA_{n2}Cs_{n3}PbX_3$, wherein MA is methylammonium, FA is formamidinium, n1 is from about 0.01 to 0.03, n2 is from about 0.82 to 0.94, and n3 is from about 0.05 to 0.015, and n1 + n2 + n3 = 1.

30. The perovskite layer of claim 29, wherein X is selected from the group consisting of fluorine, chlorine, bromine, and iodine.

31. The perovskite layer of claim 30, wherein X is a combination of two or more of fluorine, chlorine, bromine, and iodine.

32. The perovskite layer of claim 29, wherein the perovskite solar cell does not comprise additional additives.

33. A device, comprising:

a silicon solar cell having a first band gap;

a top glass sheet covering the silicon solar cell, wherein the top glass sheet comprises a top surface and a bottom surface; and

a perovskite solar cell having a second band gap, wherein the perovskite solar cell is deposited on the bottom surface of the top glass sheet.

34. The device of claim 33, wherein the silicon solar cell is electrically isolated from the perovskite solar cell.

35. The device of claim 34, wherein the silicon solar cell comprises two terminals and the perovskite solar cell comprises two terminals.

36. The device of claim 33, wherein the perovskite solar cell comprises a photoactive perovskite layer, wherein the photoactive perovskite layer comprises $CH_3NH_3PbX_3$ or $H_2NCHNH_2PbX_3$.

37. The device of claim 36, wherein X comprises iodide, bromide, chloride, or a combination thereof.

38. The device of claim 33, wherein the perovskite solar cell comprises a first transparent conductive oxide (TCO) layer and a second TCO layer.

39. The device of claim 38, wherein the first TCO layer and the second TCO layer are terminals of the perovskite solar cell.

40. The device of claim 39, wherein the first TCO layer and the second TCO layer comprise indium oxide, indium tin oxide, or aluminum zinc oxide.

41. The device of claim 33, wherein the perovskite solar cell comprises an electron transport layer (ETL) comprising phenyl-C61-butyric acid methyl ester or C60.

42. The device of claim 33, wherein the perovskite solar cell comprises a hole transport layer (HTL) comprising nickel oxide.

43. The device of claim 33, further comprising a plurality of silicon solar cells including the silicon solar cell and a plurality of perovskite solar cells including the perovskite solar cell, wherein the plurality of perovskite solar cells is laser scribed in the top glass sheet so as to voltage-match or current-match the plurality of perovskite solar cells to the plurality of silicon solar cells.

44. The device of claim 33, wherein the top glass sheet has a surface area that substantially corresponds to a surface area of a 60- or 72-cell solar panel.

45. The device of claim 33, wherein the top surface of the top glass sheet comprises an anti-reflective coating.

~~46. The device of claim 33, wherein the top surface of the top glass sheet comprises polydimethylsiloxane (PDMS).~~

~~47. The device of claim 46, wherein the PDMS comprises 1:10 alumina PDMS, textured 1:50 alumina PDMS, or textured PDMS.~~

~~48. The device of claim 33, wherein the bottom surface of the top glass sheet has a textured surface.~~

~~49. The device of claim 33, further comprising an encapsulant disposed between the silicon solar cell and the perovskite solar cell.~~

~~50. The device of claim 33, wherein the encapsulant is selected from the group consisting of ethylene-vinyl-acetate ("EVA"), thermal plastic polyolefin ("TPO"), PDMS, silicone, and paraffin.~~

~~51. The device of claim 33, wherein the silicon solar cell and the perovskite solar cell are connected electrically in parallel.~~

~~52. The device of claim 33, wherein the silicon solar cell and the perovskite solar cell are connected electrically in series.~~

~~53. The device of claim 33, wherein the second bandgap is between about 1.5 and 1.9 electron volts (eV).~~

~~54. The device of claim 33, wherein the silicon solar cell is selected from the group consisting of a monocrystalline solar cell, a polycrystalline solar cell, a passivated emitter rear contact (PERC) solar cell, an interdigitated back contact cell (IBC), and a heterojunction with intrinsic thin layer (HIT) solar cell.~~

~~55. A method for manufacturing a solar module comprising:~~

~~(a) providing a silicon solar cell having a first band gap;~~

~~(b) forming a perovskite solar cell having a second band gap in a bottom surface of a glass sheet; and~~

~~(c) affixing the glass sheet to the silicon solar cell to form the solar module such that the bottom surface of the glass sheet is adjacent to the silicon solar cell.~~