CLAIMS

1. A method of processing silicon, with a hydrogen source present, for use in the fabrication of a photovoltaic device having at least one rectifying junction, the method comprising heating at least a region of the device to at least 40°C while simultaneously illuminating at least some of the device with at least one light source whereby the cumulative power of all the incident photons with sufficient energy to generate electron hole pairs within the silicon is at least $20mW/cm^2$.

2. A method of processing silicon for use in the fabrication of a photovoltaic device having at least one rectifying junction, the method comprising heating at least a region of the device to at least 100°C, followed by cooling the device while simultaneously illuminating at least some of the device with at least one light source whereby the cumulative power of all the incident photons with sufficient energy to generate electron hole pairs within the silicon is at least $20mW/cm^2$.

3. The method of claim 1 or 2 wherein the silicon comprises a device having at least one rectifying junction.

4. The method of claim 1, 2, or 3 wherein photons generated by the at least one light source having sufficient energy to generate electron hole pairs in the silicon comprise at least 70% of the total cumulative power of all photons incident on the device from the at least one light source.

5. The method of claim 1, 2, 3 or 4 wherein the method of processing is a method of hydrogenation.

6. The method as claimed in any one of claims 1 to 5 wherein the at least one rectifying junction comprises at least one p-n junction.

7. The method as claimed in any one of claims 1 to 6 wherein the heating of the device is provided to at least 100°C.

8. The method as claimed in any one of claims 1 to 6 wherein the heating of the device is provided to at least 140°C.

9. The method as claimed in any one of claims 1 to 6 wherein the heating of the device is provided to at least 180°C.

10. The method as claimed in any one of claims 1 to 9 wherein the method further comprises ensuring that any silicon surface n-type diffused layers through which hydrogen must diffuse have peak doping concentrations of $1x10^{20}$ atoms/cm^3 or less.

11. The method as claimed in any one of claims 1 to 10 the method further comprising ensuring that any silicon surface p-type diffused layers through which hydrogen must diffuse have peak doping concentrations of $1x10^{19}$ atoms/cm^3 or less.

12. The method as claimed in any one of claims 1 to 11 the method further comprising providing one or more hydrogen sources accessible by each surface of the device.

13. The method as claimed in any one of claims 1 to 12 wherein the hydrogen source is a hydrogen source contained within the device.

14. The method as claimed in any one of claims 1 to 13 wherein the hydrogen source is a hydrogen source located externally of the device.

15. The method as claimed in any one of claims 1 to 14 wherein any silicon surface n-type diffused layers through which hydrogen must diffuse are phosphorus diffused layers.

16. The method as claimed in any one of claims 1 to 15 wherein any silicon surface p-type diffused layers through which hydrogen must diffuse are boron diffused layers.

17. The method as claimed in any one of claims 1 to 15 wherein any silicon surface p-type diffused layers through which hydrogen must diffuse are gallium diffused layers.

18. The method as claimed in any one of claims 1 to 15 wherein any silicon surface p-type diffused layers through which hydrogen must diffuse are aluminium diffused layers.

19. The method as claimed in any one of claims 1 to 18 wherein the step of heating the device to at least 40°C comprises heating all of the device, and the illumination comprises illuminating all of the device.

20. The method as claimed in any one of claims 1 to 19 wherein the illumination from the at least one light sources be provided at levels whereby the cumulative power of all the incident photons with sufficient energy to generate electron hole pairs within the silicon is at least 50 mW/cm^2, or 60 mW/cm^2, or 70 mW/cm^2, or 80 mW/cm^2, or 90 mW/cm^2, or 100 mW/cm^2, or 150 mW/cm^2, 200 mW/cm^2, or 300 mW/cm^2, or 400 mW/cm^2, or 500 mW/cm^2, or 600 mW/cm^2, or 700 mW/cm^2, or 800 mW/cm^2, or 900 mW/cm^2, or 1000 mW/cm^2, or 1500 mW/cm^2, 2000 mW/cm^2, or 3000 mW/cm^2, or 5000 mW/cm^2, or 10000 mW/cm^2, or 15000 mW/cm^2, or 20000 mW/cm^2, or up to a light intensity at which the silicon begins to melt.

21. The method as claimed in any one of claims 1 to 20 wherein the heating of the device is provided to at least or to at least 200°C, or to at least 300°C, or to at least 400°C, or to at least 500°C, or to at least 600°C, or to at least 700°C, or to at least 800°C, or to at least 900°C, or to at least 1,000°C, or to at least 1,200°C or to a temperature at which the silicon begins to melt.

22. The method as claimed in any one of claims 10 to 21 wherein the silicon surface n-type diffused layers have peak doping concentrations of $1x10^{19}$ $atoms/cm^3$ or less or $1x10^{18}$ $atoms/cm^3$ or less or $1x10^{17}$ $atoms/cm^3$ or less or $1x10^{16}$ $atoms/cm^3$ or less.

23. The method as claimed in any one of claims 15 to 22 wherein the silicon surface phosphorus diffused layers have peak doping concentrations of $1x10^{19}$ atoms/cm^3 or less or $1x10^{18}$ atoms/cm^3 or less or $1x10^{17}$ atoms/cm^3 or less or $1x10^{16}$ atoms/cm^3 or less.

24. The method as claimed in any one of claims 11 to 23 wherein the silicon surface p-type diffused layers have peak doping concentrations of $1x10^{18}$ atoms/cm^3 or less or $1x10^{17}$ atoms/cm^3 or less or $1x10^{16}$ atoms/cm^3 or less.

25. The method as claimed in any one of claims 16 to 23 wherein the silicon surface boron diffused layers have peak doping concentrations of $1x10^{18}$ atoms/cm^3 or less or $1x10^{17}$ atoms/cm^3 or less or $1x10^{16}$ atoms/cm^3 or less.

26. The method as claimed in any one of claims 17 to 23 wherein the silicon surface galium diffused layers have peak doping concentrations of $1x10^{18}$ atoms/cm^3 or less or $1x10^{17}$ atoms/cm^3 or less or $1x10^{16}$ atoms/cm^3 or less.

27. The method as claimed in any one of claims 18 to 23 wherein the silicon surface aluminium diffused layers have peak doping concentrations of $1x10^{18}$ atoms/cm^3 or less or $1x10^{17}$ atoms/cm^3 or less or $1x10^{16}$ atoms/cm^3 or less.

28. The method as claimed in any one of claims 1 to 27 wherein the processing method is enhanced by heating the silicon photovoltaic junction device to a temperature less than 500°C, or 400°C, or 350°C, or 300°C, or 250°C, or 200°C, or 150°C, or 100°C, or 50°C while the silicon photovoltaic junction device is illuminated.

29. The method as claimed in any one of claims 1 to 28 wherein the step of heating the device is followed by a cooling step, and illumination of the device is continued during the cooling step.

30. The method as claimed in any one of claims 1 to 28 wherein the step of heating the device to at least 40°C is followed by a cooling step, and illumination is varied during the cooling step, to control the amount of hydrogen in a given charge state.

31. The method as claimed in claim 29 or 30 wherein illumination is maintained or varied during the cooling step, while the temperature is reduced to below a predetermined threshold.

32. The method as claimed in claim 29 or 30 wherein illumination is maintained or varied during the cooling step, while the temperature is reduced back below 100°C.

33. The method as claimed in claim 29 or 30 wherein illumination is maintained or varied during the cooling step, while the temperature is reduced back to an ambient temperature.

34 The method as claimed in any one of claims 1 to 33 wherein minority carrier concentrations are controlled during a cool-down period after heating the device, by

illuminating the device while the device is cooling to maintain hydrogen charge states during cool-down which minimise reactivation of defects to which hydrogen has previously bound.

35. The method as claimed in any one of claims 1 to 34 wherein the process is a process performed at temperatures greater than 200°C, after a hydrogenation process has been performed on the device.

36. The method as claimed in claim 35 wherein after the processes performed at temperatures greater than 200°C, after a hydrogenation process has been performed on the device, the device is cooled and illumination of the device with a hydrogen source present is continued while the device cools.

37. The method as claimed in any one of claims 1 to 36 wherein the process is performed on a region of the device, by performing the heating locally on region of the device to be processed in the presence of the light source.

38. The method as claimed in any one of claims 1 to 36 wherein the process is performed on a region of the device, by performing the heating locally on a region of the device adjacent to the region to be processed, in the presence of the light source.

39. The method as claimed in any one of claims 1 to 38 wherein a laser is used to perform both the heating and illumination functions simultaneously.

40. The method as claimed in any one of claims 1 to 39 wherein the hydrogen sources comprise a layer or layers of silicon nitride, silicon oxynitride or layers of amorphous silicon.

41. The method of claim 40 wherein the hydrogen sources are deposited onto surface passivating layers comprising silicon dioxide and aluminium oxide.

42. The method as claimed in any one of claims 1 to 41 wherein the hydrogen sources comprise a layer or layers of aluminium oxide.

43. The method as claimed in any one of claims 1 to 41 wherein the hydrogen sources comprise or forming gas or plasma source of atomic hydrogen.

44. The method as claimed in any one of claims 1 to 43 wherein the device is absent of any hydrogen sinks.

45. The method as claimed in claim 44 wherein the device is absent of a hydrogen sink which is one of a metal/silicon interfaces, a region of the silicon with excessive levels of contaminants or a region of the silicon with a doping impurity above the solid solubility level of the impurity in silicon.

46. The method as claimed in any one of claims 1 to 43 wherein the device includes a hydrogen sink.

47. The method as claimed in claim 46 wherein the device includes a hydrogen sink which is one of a metal/silicon interface or a region of the silicon containing excessive levels of contaminants or a region of the silicon containing a doping

impurity above the solid solubility level of the impurity in silicon, and the method further comprises isolating the hydrogen diffused into the silicon device from the hydrogen sink.

48. The method of claim 46 wherein a region of impurity is created with an impurity type and concentration profile to create an internal electric field within the silicon which inhibits movement of the hydrogen towards the hydrogen sink to thereby isolate the hydrogen diffused into the silicon device from the hydrogen sink.

49. The method of claim 46 wherein dopant concentration is increased in a region around the sink to control the hydrogen charge state in the region around the sink to thereby reduce the mobility for hydrogen to isolate the hydrogen diffused into the silicon device from the hydrogen sink.

50. The method of claim 49 wherein increased dopant concentration in a region around the sink does not extend to isolate the bulk of the silicon to be processed from the surface through which the hydrogen must diffuse.

51. The method of as claimed in any one of claims 1 to 50 wherein the device has a metal silicon/interface, the method further comprising forming an isolation region between the metal silicon/interface and the bulk of the silicon to be processed, the isolation region being doped with a dopant of the same polarity as the bulk of the silicon to be processed and at a concentration greater than 10^{19}.

52. The method of as claimed in any one of claims 1 to 50 wherein the device comprises a p-type wafer which has a metal silicon/interface for electrical connection to the p-type bulk of the device, the method further comprising forming an boron doped region between the metal silicon/interface and the p-type bulk of the silicon device, the isolation region being doped at a concentration greater than 10^{19}.

53. The method of as claimed in any one of claims 1 to 50 wherein the device comprises an n-type wafer which has a metal silicon/interface for electrical connection to the n-type bulk of the device, the method further comprising forming an phosphorous doped region between the metal silicon/interface and the n-type bulk of the silicon device, the isolation region being doped at a concentration 10^{19}.

54. The method as claimed in any one of claims 1 to 53 wherein an electric field is applied to promote diffusion and/or drift of hydrogen toward regions to be hydrogenated.

55. The method as claimed in any one of claims 1 to 54 wherein an electric field is applied to inhibit diffusion and/or drift of hydrogen out of the device after hydrogenation.

56. The method as claimed in any one of claims 54 or 55 wherein the electric field is an electrostatic field created or enhanced by applying layers of dielectric material to a surface of the device.

57. The method as claimed in any one of claims 54 or 55 wherein an electric field is an electrostatic field created or enhanced by charging a surface of the device with an electrostatic gun.

58. The method as claimed in any one of claims 54 or 55 wherein the electric field is a field applied externally to the device.

59. The method as claimed in any one of claims 1 to 58 wherein the silicon photovoltaic junction device has a structure designed to minimise the escape of hydrogen from the active area after hydrogenation processing the method further comprising forming a doped barrier region having a doping concentration level greater than an adjacent hydrogenated region.

60. The method as claimed in any one of claims 1 to 59 wherein the silicon photovoltaic junction device has a structure designed to minimise the escape of hydrogen from the active area after hydrogenation processing, the method further comprising forming a hydrogen source at both surfaces of the silicon photovoltaic junction device.

61. The method as claimed in any one of claims 1 to 60 wherein an intensity of illumination applied to the device is varied during the hydrogenation or other thermal process.

62. The method as claimed in claim 61 wherein the intensity of illumination applied to the device is increased during a cooling stage after the hydrogenation or other thermal process.

63. The method as claimed in any one of claims 62 wherein the intensity of illumination applied to the device is increased with decreasing temperature of the device.

64. The method as claimed in claims 63 wherein during a hydrogenation process, or during a process performed at greater than 200°C after hydrogenation and /or during cooling after such a process, illumination applied to the device is pulsed.

65. The method as claimed in claims 1 to 64 wherein during hydrogenation, a process performed at greater than 200°C after hydrogenation and /or during cooling, the source of illumination is an array of LEDs.

66. The method as claimed in claims 1 to 65 wherein a source of illumination during hydrogenation, a process performed at greater than 200°C after hydrogenation and /or during cooling, is one or more infra-red lamps.

67. The method as claimed in claims 1 to 65 wherein a source of illumination during hydrogenation, a process performed at greater than 200°C after hydrogenation and /or during cooling, is a laser.

68. The method as claimed in claims 1 to 67 wherein a hydrogenation process or a process performed at greater than 200°C after hydrogenation, is performed in a belt

furnace having separate heating and cooling zones each of which are provided with illumination to illuminate the device during heating and cooling steps.

67. The method as claimed in any one of claims 1 to 66 wherein the intensity of illumination applied to the device is controlled to maintain the Fermi level at a value of 0.5 to 0.22ev above mid-gap.

CLAIMS:

1. A method of processing silicon, with a hydrogen source present, for use in the fabrication of a photovoltaic device having at least one rectifying junction, the method comprising heating at least a region of the device to at least 100 °C while simultaneously illuminating at least some of the device with at least one light source whereby the cumulative power of all the incident photons with sufficient energy to generate electron hole pairs within the silicon is at least 20 mW/cm^2.

2. The method of claim 1 wherein photons generated by the at least one light source having sufficient energy to generate electron hole pairs in the silicon comprise at least 70% of the total cumulative power of all photons incident on the device from the at least one light source.

3. The method as claimed in claim 1 wherein the heating of the device is provided to at least 200 °C.

4. The method as claimed in claim 1 wherein the method further comprises ensuring that any silicon surface n-type doped layers through which hydrogen must diffuse have peak doping concentrations of 1×10^{20} $atoms/cm^3$ or less.

5. The method as claimed in claim 1 the method further comprising ensuring that any silicon surface p-type doped layers through which hydrogen must diffuse have peak doping concentrations of 1×10^{19} $atoms/cm^3$ or less.

6. The method as claimed in claim 1 the method further comprising providing one or more hydrogen sources accessible by a front surface and a rear surface of the device.

7. The method as claimed in claim 1 wherein the hydrogen source is a hydrogen source contained within the device.

8. The method as claimed in claim 1 wherein the hydrogen source is a hydrogen source located externally of the device.

9. The method as claimed claim 1 wherein the step of heating of the device to at least 100 °C is followed by cooling of the device, and illumination is varied during the cooling, to control the amount of hydrogen in a given charge state.

10. The method as claimed in claim 9 wherein illumination is maintained or varied during the cooling step, until the temperature is reduced to below a predetermined threshold.

11. The method as claimed in claim 9 wherein illumination is maintained or varied during the cooling step, until the temperature is reduced back below 100 °C.

12. The method as claimed in claim 1 wherein after a processes is performed at temperatures greater than 200 °C, after a hydrogenation process has been performed on the device, the device is cooled and illumination of the device with a hydrogen source present is continued while the device cools.

13. The method as claimed in claim 1 wherein an intensity of illumination applied to the device is varied during the hydrogenation or other thermal process.

14. The method as claimed in claim 1 wherein during a hydrogenation process, or during a process performed at greater than 200 °C after hydrogenation and/or during cooling after such a process, illumination applied to the device is pulsed.

15. The method as claimed in any claim 1 wherein the intensity of illumination applied to the device is controlled to maintain the Fermi level at a value of 0.5 to 0.22 ev above mid-gap.

16. The method as claimed in claim 1 wherein the heating of the device is provided to at least 300 °C.

17. The method as claimed in claim 1 wherein the hydrogen sources comprise a layer or layers of PECVD deposited material containing oxygen.

18. The method as claimed in claim 1 wherein hydrogen atoms passivate recombination sites within the device to increase wafer minority carrier lifetimes.

19. The method as claimed in claim 17 wherein hydrogen atoms passivate recombination sites within the device to increase wafer minority carrier lifetimes by at least a factor of two.

20. The method as claimed in claim 1 wherein after heating the device, the device is rapidly cooled by blowing cool air onto the device.

21. The method as claimed in claim 1 wherein a localised region which is hotter than a remainder of the device is rapidly cooled by transfer of heat to the remainder of the device acting as a heat sink.