CLAIMS

1. A photovoltaic device comprising:

a bonding layer which is disposed in contact with a substrate having an insulating surface;

a first electrode over the bonding layer;

a single crystal semiconductor layer over the first electrode;

a first impurity semiconductor layer formed in an opposite plane of the single crystal semiconductor layer to the first electrode;

a protective film provided over the first impurity semiconductor layer; and

a second electrode which is in contact with the first impurity semiconductor layer.

2. The photovoltaic device according to claim 1, wherein a second impurity semiconductor region is provided in the single crystal semiconductor layer so as to be in contact with the first electrode.

3. The photovoltaic device according to claim 2, wherein a silicon nitride layer is provided between the bonding layer and the first electrode.

4. The photovoltaic device according to claim 1, wherein a thickness of the single crystal semiconductor layer is 0.1 to 10 μm.

5. The photovoltaic device according to claim 1, wherein the substrate is one kind selected from aluminosilicate glass substrates, aluminoborosilicate glass substrates, or barium borosilicate glass substrates.

6. A photovoltaic device comprising:

a barrier layer provided over one surface of a substrate, a first bonding layer provided over the barrier layer,

a second bonding layer which is disposed in contact with the first bonding layer;

a first electrode over the bonding layer;

a single crystal semiconductor layer over the first electrode;

a first impurity semiconductor layer formed in an opposite plane of the single crystal semiconductor layer to the first electrode;

a protective film provided over the first impurity semiconductor layer; and

a second electrode which is in contact with the first impurity semiconductor layer.

7. The photovoltaic device according to claim 6, wherein a thickness of the single crystal semiconductor layer is 0.1 to 10 μm.

8. The photovoltaic device according to claim 6, wherein the substrate is one kind selected from aluminosilicate glass substrates, aluminoborosilicate glass substrates, or barium borosilicate glass substrates.

9. A photovoltaic device comprising:

a barrier layer provided over one surface of a substrate;

a first bonding layer provided over the barrier layer;

a single crystal semiconductor layer with a first plane on a first bonding layer side on which a silicon oxide layer is formed and with a second plane on a side opposite to the first bonding layer side in which a first impurity semiconductor layer and a second impurity semiconductor layer are formed so as to be separated from each other;

a second electrode which is in contact with the first impurity semiconductor layer;

a first electrode which is in contact with the second impurity semiconductor layer; and

a protective layer provided over the second plane of the single crystal semiconductor layer between the first electrode and the second electrode,

wherein the first bonding layer and the silicon oxide layer are bonded to each other.

10. The photovoltaic device according to claim 1 to 5, wherein a thickness of

the single crystal semiconductor layer is 0.1 to 10 μm.

11. The photovoltaic device according to any one of claims 1 to 6, wherein the substrate is one kind selected from aluminosilicate glass substrates, aluminoborosilicate glass substrates, or barium borosilicate glass substrates.

12. A method for manufacturing a photovoltaic device, comprising:

introducing one kind of ions or plural kinds of ions of different masses each comprising a same atom, which are produced by subjecting a source gas selected from hydrogen, helium, or halogen to plasma excitation, into a single crystal semiconductor substrate to form a separation layer in a region of the single crystal semiconductor substrate at a predetermined depth from the surface of the single crystal semiconductor substrate,

forming a silicon oxide film over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas;

bonding the single crystal semiconductor substrate to a substrate having an insulating surface by superposition thereof with the silicon oxide film interposed therebetween;

performing thermal treatment in a state where the single crystal semiconductor substrate and the substrate having an insulating surface are superposed on each other to generate cleavage in the separation layer, and separating and removing the single crystal semiconductor substrate with a single crystal semiconductor layer left over the substrate having an insulating surface, and

forming an impurity semiconductor layer as a photoelectric conversion layer by addition of an impurity element to the single crystal semiconductor layer.

13. The method for manufacturing a photovoltaic device according to claim 12, wherein as the organic silane gas, one kind selected from tetraethoxysilane (TEOS) (chemical formula: $Si(OC_2H_5)_4$), trimethylsilane (TMS) (chemical formula: $(CH_3)_3SiH$), tetramethylcyclotetrasiloxane (TMCTS), octamethylcyclotetrasiloxane (OMCTS), hexamethyldisilazane (HMDS), triethoxysilane (chemical formula: $SiH(OC_2H_5)_3$), or trisdimethylaminosilane (chemical formula: $SiH(N(CH_3)_2)_3$) is used.

14. The method for manufacturing a photovoltaic device according to claim 12, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is a temperature at which an element introduced into the separation layer does not leave, and the thermal treatment is performed at a temperature at which an element introduced into the separation layer leaves.

15. The method for manufacturing a photovoltaic device according to claim 12, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is 350°C or lower, and the thermal treatment is performed at 400°C or higher.

16. The method for manufacturing a photovoltaic device according to claim 12, wherein the separation layer is formed by introduction of H^+, H_2^+, and H_3^+ ions with a high proportion of H_3^+ ions.

17. A method for manufacturing a photovoltaic device, comprising:

introducing one kind of ions or plural kinds of ions of different masses each comprising the same atom, which are produced by subjecting a source gas selected from hydrogen, helium, or halogen to plasma excitation, into a single crystal semiconductor substrate to form a separation layer in a region of the single crystal semiconductor substrate at a predetermined depth from a surface of the single crystal semiconductor substrate,

adding an impurity element which controls conductivity in a region of the single crystal semiconductor substrate at a depth shallower than that of the separation layer formed in the single crystal semiconductor substrate to form an impurity semiconductor layer;

forming a first electrode over the impurity semiconductor layer;

forming a silicon oxide film over the first electrode by a chemical vapor deposition method with the use of an organic silane gas;

bonding the single crystal semiconductor substrate to a substrate having an insulating surface by superposition thereof with the silicon oxide film interposed therebetween;

performing thermal treatment in a state where the single crystal semiconductor substrate and the substrate having an insulating surface are superposed on each other to generate cleavage in the separation layer, and separating the single crystal semiconductor substrate to form a single crystal semiconductor layer over the substrate having an insulating surface;

forming an impurity semiconductor layer having opposite conductivity to the impurity semiconductor layer, in the single crystal semiconductor layer, and

forming a second electrode over the impurity semiconductor layer having opposite conductivity.

18. The method for manufacturing a photovoltaic device according to claim 17, wherein as the organic silane gas, one kind selected from tetraethoxysilane (TEOS) (chemical formula: $Si(OC_2H_5)_4$), trimethylsilane (TMS) (chemical formula: $(CH_3)_3SiH$), tetramethylcyclotetrasiloxane (TMCTS), octamethylcyclotetrasiloxane (OMCTS), hexamethyldisilazane (HMDS), triethoxysilane (chemical formula: $SiH(OC_2H_5)_3$), or trisdimethylaminosilane (chemical formula: $SiH(N(CH_3)_2)_3$) is used.

19. The method for manufacturing a photovoltaic device according to claim 17, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is a temperature at which an element introduced into the separation layer does not leave, and the thermal treatment is performed at a temperature at which an element introduced into the separation layer leaves.

20. The method for manufacturing a photovoltaic device according to claim 17, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is 350°C or lower, and the thermal treatment is performed at 400°C or higher.

21. The method for manufacturing a photovoltaic device according to claim 13, wherein the separation layer is formed by introduction of H^+, H_2^+, and H_3^+ ions with a high proportion of H_3^+ ions.

What is claimed is:

1. A method for manufacturing a photovoltaic device, comprising:

introducing one kind of ions or plural kinds of ions of different masses each comprising a same atom, which are produced by subjecting a source gas selected from hydrogen, helium, or halogen to plasma excitation, into a single crystal semiconductor substrate to form a separation layer in a region of the single crystal semiconductor substrate at a predetermined depth from the surface of the single crystal semiconductor substrate,

forming a silicon oxide film over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas;

bonding the single crystal semiconductor substrate to a substrate having an insulating surface by superposition thereof with the silicon oxide film interposed therebetween;

performing thermal treatment in a state where the single crystal semiconductor substrate and the substrate having an insulating surface are superposed on each other to generate cleavage in the separation layer, and separating and removing the single crystal semiconductor substrate with a single crystal semiconductor layer left over the substrate having an insulating surface, and

forming an impurity semiconductor layer as a photoelectric conversion layer by addition of an impurity element to the single crystal semiconductor layer.

2. The method for manufacturing a photovoltaic device according to claim 1, wherein as the organic silane gas, one kind selected from tetraethoxysilane (TEOS) (chemical formula: $Si(OC_2H_5)_4$), trimethylsilane (TMS) (chemical formula: $(CH_3)_3SiH$), tetramethylcyclotetrasiloxane (TMCTS), octamethylcyclotetrasiloxane (OMCTS), hexamethyldisilazane (HMDS), triethoxysilane (chemical formula: $SiH(OC_2H_5)_3$), or trisdimethylaminosilane (chemical formula: $SiH(N(CH_3)_2)_3$) is used.

3. The method for manufacturing a photovoltaic device according to claim 1, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is a temperature at which an element introduced into the separation layer does not leave, and the thermal treatment is performed at a temperature at which an element introduced into the separation layer leaves.

4. The method for manufacturing a photovoltaic device according to claim 1, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is 350° C or lower, and the thermal treatment is performed at 400° C or higher.

5. The method for manufacturing a photovoltaic device according to claim 1, wherein the separation layer is formed by introduction of H^+, H_2^+, and H_3^+ ions with a high proportion of H_3^+ ions.

6. A method for manufacturing a photovoltaic device, comprising:

introducing one kind of ions or plural kinds of ions of different masses each comprising the same atom, which are produced by subjecting a source gas selected from hydrogen, helium, or halogen to plasma excitation, into a single crystal semiconductor substrate to form a separation layer in a region of the single crystal semiconductor substrate at a predetermined depth from a surface of the single crystal semiconductor substrate,

adding an impurity element which controls conductivity in a region of the single crystal semiconductor substrate at a depth shallower than that of the separation layer formed in the single crystal semiconductor substrate to form an impurity semiconductor layer;

forming a first electrode over the impurity semiconductor layer;

forming a silicon oxide film over the first electrode by a chemical vapor deposition method with the use of an organic silane gas;

bonding the single crystal semiconductor substrate to a substrate having an insulating surface by superposition thereof with the silicon oxide film interposed therebetween;

performing thermal treatment in a state where the single crystal semiconductor substrate and the substrate having an insulating surface are superposed on each other to generate cleavage in the separation layer, and separating the single crystal semiconductor substrate to form a single crystal semiconductor layer over the substrate having an insulating surface;

forming an impurity semiconductor layer having opposite conductivity to the impurity semiconductor layer, in the single crystal semiconductor layer, and

forming a second electrode over the impurity semiconductor layer having opposite conductivity.

7. The method for manufacturing a photovoltaic device according to claim 6, wherein as the organic silane gas, one kind selected from tetraethoxysilane (TEOS) (chemical formula: $Si(OC_2H_5)_4$), trimethylsilane (TMS) (chemical formula: $(CH_3)_3SiH$), tetramethylcyclotetrasiloxane (TMCTS), octamethylcyclotetrasiloxane (OMCTS), hexamethyldisilazane (HMDS), triethoxysilane (chemical formula: $SiH(OC_2H_5)_3$), or trisdimethylaminosilane (chemical formula: $SiH(N(CH_3)_2)_3$ is used.

8. The method for manufacturing a photovoltaic device according to claim 6, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is a temperature at which an element introduced into the separation layer does not leave, and the thermal treatment is performed at a temperature at which an element introduced into the separation layer leaves.

9. The method for manufacturing a photovoltaic device according to claim 6, wherein a temperature at which the silicon oxide film is formed over the single crystal semiconductor substrate by a chemical vapor deposition method with the use of an organic silane gas is 350° C or lower, and the thermal treatment is performed at 400° C or higher.

10. The method for manufacturing a photovoltaic device according to claim 2, wherein the separation layer is formed by introduction of H^+, H_2^+, and H_3^+ ions with a high proportion of H_3^+ ions.