first major surface side, removing the primary damaged layer mechanically or chemically, inflicting a new damage by another mechanical work other than the slicing work, to form a secondary damaged layer thinner than the primary damaged layer, anisotropically etching the secondary damaged layer to form a texture structure, and forming a light-receiving side electrode on the texture structure.

Citation List

Patent Document

[0007]

Patent Document 1: JP-A H09-129907

Patent Document 2: JP-A H10-7493

Patent Document 3: JP-A 2005-209726

SUMMARY OF INVENTION

Technical Problem

[0008]

Embodiments~~An object~~ of the invention seek~~is~~ to provide a solar cell and manufacture method that can improve the conversion efficiency and bulk lifetime of a solar cell of quality in a very efficient way without increasing the number of steps.

Solution to Problem

[0009]

Making extensive investigations to attain the above object, the inventors have found that with respect to a monocrystalline silicon substrate which is prepared by slicing a monocrystalline silicon ingot so that the substrate may include a slice damaged layer on its surface, better results can be~~are~~ obtained if the damaged layer is chemically removed, but not completely, so that the damaged layer preferably having a thickness of 0.2 to 5 μm is left on the substrate even after texture formation. More particularly, it is believed in the art that if the damaged layer originating from the slicing step during the preparation of

the monocrystalline silicon substrate is not completely removed, problems arise that the surface recombination rate is increased and the solar cell performance is degraded. Therefore, texture formation is carried out after the damaged layer originating from the slicing step is removed with an alkaline aqueous solution. Since the work damaged layer originating from the slicing step is as thick as 10 μm or more, deep chemical etching is carried out until the damaged layer is removed almost completely. Quite unexpectedly, the inventors have found through extensive investigations that if the damaged layer originating from the slicing step is removed, but not completely, so that the damaged layer having a thickness of 0.2 to 5 μm is intentionally left on the substrate, then the getter effect can be~~is~~ enhanced, the bulk lifetime can be~~is~~ increased, and the solar cell performance can be~~is~~ improved.

[0010]

It is noted that Patent Document 3 cited above discloses to form a damaged layer prior to texture formation. This method involves inflicting a new damage by another mechanical work other than the damage by slicing work, to form a secondary damaged layer thinner than the primary damaged layer, subjecting the secondary damaged layer to anisotropic etching to form a texture structure, and forming a light-receiving side electrode on the texture structure. After the damaged layer originating from the slicing step is completely etched away, another damaged layer is newly formed. Thus, the method includes cumbersome operations and requires a careful control of the thickness of the secondary damaged layer. In contrast, the method as disclosed in embodiments of~~f~~ the present invention does not require to form a damaged layer separately because the damaged layer left after texture formation originates from the damaged layer formed by the slicing step. Also, an improvement in bulk lifetime can be~~is~~ achieved merely by retaining only a fraction of the damaged layer originating from the slicing step, which is believed in the prior art to be removed in order to reduce the surface recombination rate, as discussed above.

[0011]

According~~ly,~~ to an aspect of the present invention, there is provide~~s a solar cell and a method of manufacturing the same as defined below.~~

~~Claim 1:~~

~~A~~ a solar cell comprising a monocrystalline silicon substrate having a texture structure at its surface, the monocrystalline silicon substrate including a damaged layer near its surface, the damaged layer originating from a slicing step during the preparation of the substrate~~.~~, wherein the damaged layer has a depth of 0.2 to 5 μm.

~~Claim 2:~~

~~The solar cell of claim 1 wherein the damaged layer has a depth of 0.2 to 5 μm.~~

~~Claim 3:~~

~~The solar cell of claim 1 or 2 wherein~~ T~~t~~he monocrystalline silicon substrate has a major surface of {100} plane.

~~Claim 4:~~

According to another aspect of the present invention, there is provided a method of manufacturing a solar cell, comprising the steps of forming a texture on a monocrystalline silicon substrate by chemical etching, said monocrystalline silicon substrate having on its surface a damaged layer originating from a slicing step during the preparation of the substrate, forming a p-n junction, and forming electrodes, wherein the step of forming a texture is carried out such that the damaged layer originating from a slicing step during the preparation of the substrate is left behind, and the damaged layer having a depth of 0.2 to 5 μm thus remains near the surface of the textured substrate.

~~Claim 5:~~

~~The method of claim 4 wherein the step of forming a texture is carried out such that the damaged layer may have a depth of 0.2 to 5 μm after the texture formation.~~

~~Claim 6:~~

~~The method of claim 4 or 5 wherein~~ ~~t~~The monocrystalline silicon substrate has a major surface of {100} plane, and the chemical etching is anisotropic etching using an alkaline aqueous solution so that the texture structure may be~~is~~ formed as

an arrangement of regular pyramid protrusions delimited by four {111} planes.

~~Claim 7~~

~~The method of any one of claims 4 to 6 wherein~~ ~~t~~The alkaline aqueous solution used for chemical etching of the surface of the monocrystalline silicon substrate is an aqueous solution containing sodium hydroxide, potassium hydroxide, potassium carbonate, sodium carbonate or sodium hydrogencarbonate.

[0012]

With the method of manufacturing a solar cell according to embodiments of the invention, crystal defects introduced in the damaged layer left on the texture function as getter sites for impurity atoms, prolonging the minority carrier lifetime (or bulk lifetime) and contributing to an improvement in conversion efficiency.

[0013]

Notably, the damaged layer to be left should desirably have a depth of 0.2 to 5 μm. The damaged layer with a depth in excess of 5 μm may cause to increase the surface recombination rate, resulting in a solar cell having degraded properties. The damaged layer with a depth of less than 0.2 μm may achieve insufficient getter effect.

[0014]

The monocrystalline silicon substrate may have a major surface of {100} plane. When anisotropic etching is carried out using an alkaline aqueous solution, the texture structure is formed as an arrangement of regular pyramid protrusions delimited by four {111} planes. A better antireflective effect may be~~is~~ also achievable.

[0015]

The damaged layer used herein may be one originating from the slicing step. Then, the number of steps may~~is~~ not be increased because of no need to inflict new damage.

As used herein, the term "damaged layer" refers to a layer of silicon crystal which consists of a regular

arrangement of silicon atoms in theory, but contains many dislocation defects, cracks and fractures caused by the wire saw or similar tool for slicing.

Advantageous Effects of Invention

[0016]

For the monocrystalline silicon substrate according to embodiments of the invention, the damaged layer originating from the slicing step during the preparation of the substrate and left near the surface functions as getter site, may contribute~~ing~~ to an improvement in the lifetime of minority carriers in the substrate. By virtue of this effect, the solar cell performance may be~~is~~ dramatically improved. Also the number of steps may~~is~~ not be increased because the damage by slicing is utilized rather than inflicting new damage.

BRIEF DESCRIPTION OF DRAWINGS

[0017]

FIG. 1 is a schematic cross-sectional view of one embodiment of solar cell to be manufactured by the method of the invention.

FIG. 2 is a perspective view of a texture structure formed on the substrate surface.

FIG. 3 illustrates in sequence the overall method of manufacturing a solar cell according to the invention.

DESCRIPTION OF EMBODIMENTS

[0018]

The structure of a solar cell according to the invention is described below with reference to the drawings although the invention is not limited to the solar cell of the illustrated structure.

Referring to FIG. 1, a solar cell 100 includes a p-type monocrystalline silicon substrate 1 doped with boron, for example, (simply referred to as "substrate," hereinafter) and an n-type emitter layer 42 formed on a first major surface (or light-receiving surface) of substrate 1, to