Appeal decision

Appeal No. 2014-25296

Germany
Appellant HANWHA Q CELLS GMBH

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The case of appeal against an examiner's decision of refusal of Japanese Patent Application No. 2012-515353, entitled "Solar Cell and Manufacturing Method Thereof" [the application's international publication was made on Dec. 23, 2010: WO 2010/145648, and national publication of the translated version on Nov. 29, 2012: National Publication of International Patent Application No. 2012-530361] has resulted in the following appeal decision:

Conclusion

The appeal of the case was groundless.

Reason

1. History of the procedures

The present application is an application that was originally filed on May 31, 2010 as an International Patent Application (claim of priority under the Paris Convention was received by the foreign receiving office on Jun. 16, 2009, Germany), the reason for refusal was noticed on Jan. 6, 2014, a written opinion and a written amendment were submitted on May 7, 2014, and a decision of refusal was made on Aug. 1, 2014. Then, in response to this, a demand for appeal against an examiner's decision of refusal was filed on Dec. 10, 2014, and, in conjunction with this, an amendment was made at the same time. After that, a reconsideration report made to the JPO Commissioner in the procedure of reconsideration by examiners before appeal proceedings was made on Jan. 13, 2015, and, a written statement was submitted on Apr. 23, 2015.

2. The invention

The invention according to claim 1 of the present application (hereinafter, referred to as the "Invention") is acknowledged as follows as described in claim 1 of the scope of claims that was amended by the written amendment dated Dec. 10, 2014.

"A solar cell, comprising: at least front-face-side contact metallization and back-face-side contact metallization; a semiconductor layer (2); and a passivation layer (3) that is arranged on a surface of the semiconductor layer (2), and is useful for passivation of the semiconductor layer surface (20), wherein the passivation layer (3) comprises a chemically passivating passivation sub-layer (31) and a field-effect-passivating passivation sub-layer (33) arranged in a manner one above the other on the semiconductor layer surface (20), wherein

the chemically passivating passivation sub-layer (31) is in contact with the field-effect-passivating passivation sub-layer (33) directly, and wherein

(i) the field-effect-passivating passivation sub-layer (33) comprises aluminum oxide, aluminum fluoride, silicon nitride, aluminium oxynitride, and/or some other compound composed of aluminum oxide and one or more further elements, and

(ii) a covering layer comprising silicon nitride (SiN_X) is attached on the passivation layer."

3. Cited Document

(1) Described matters in citation

In International publication No. WO 2008/065918 (Hereinafter, referred to as "Cited Document") that was cited in the reasons for refusal stated in the examiner's decision, and that became available to the public through electric communication lines in advance of the priority date of the present application, there are described the following matters (the underlines are applied by the body).

A "[0001] The present invention relates to a solar cell and a manufacturing method thereof. And, more specifically, it relates to a solar cell using a passivation film with a high refractive index on a surface opposite the light-receiving surface of a silicon substrate, and a manufacturing method thereof."

B "[0005] As a method for suppressing recombination of minority carriers on a substrate surface, a method to form a passivation film is used. However, in a back surface junction solar cell, a p area and an n area are formed in a same surface, and, therefore, development of a passivation film that is effective for both of the p area and the n area is strongly desired."

C "[0010] In view of the above-mentioned problems , it is an object of the present invention to provide a solar cell in which a passivation film that is highly effective for both a p area and an n area in a surface of a silicon substrate in a solar cell is formed.

[Means for Solving the Problems]

[0011] The present invention relates to a solar cell in which a first passivation film made of a silicon nitride film is formed on a surface opposite the light-receiving surface of a silicon substrate, and the refractive index of the film is equal to or more than 2.6.

[0012] In addition, it is preferred that a solar cell of the present invention be of a back surface junction type having a pn junction formed on a surface opposite the light-receiving surface of a silicon substrate.

[0013] Furthermore, it is preferred that a solar cell of the present invention have a second passivation film including a silicon oxide film and/or an aluminum oxide film formed between the first passivation film and the silicon substrate."

D "[0017] It is also preferred that a fabricating method of the present invention include a step of forming the second passivation film including a silicon oxide film between the silicon substrate and the first passivation film, and the silicon oxide film be formed by a thermal oxidation method.

[0018] It is preferred that the fabricating method of the present invention include a step of annealing the silicon substrate after the step of forming the first passivation film.

[0019] In the fabricating method of the present invention, it is preferred that the step of annealing be carried out in an atmosphere including hydrogen and an inactive gas.

[0020] It is also preferred that, in the fabricating method of the present invention, the step of annealing be carried out in an atmosphere including 0.1-4.0% hydrogen.

[0021] It is further preferred that, in the fabricating method of the present invention, the step of annealing be carried out in a range of 350-600 degrees C for 5 minutes-1 hour."

E "[0032] <Passivation film >

The first passivation film of the present invention is made of a silicon nitride film, and the refractive index of the film is equal to or more than 2.6, and, more preferably, is equal to or more than 2.8. The second passivation film is a film that includes a silicon oxide film and/or aluminum oxide film. The second passivation film may be a laminated body of a silicon oxide film and an aluminum oxide film, or may be one made of an aluminum oxide film only, or may be one that is made of a silicon oxide film only. In this regard, however, it is desired in particular that the second passivation film be a film made of a silicon oxide film only.

[0033] <<First passivation film>>

FIG. 3(a) shows relation between a refractive index of a silicon nitride film formed on an n-type silicon substrate and lifetime of minority carriers in the silicon substrate, and FIG. 3(b) indicates relation between a refractive index of a silicon nitride film formed on an n-type silicon substrate having a p area formed on its surface, and lifetime of minority carriers in the silicon substrate. The horizontal axes in FIG. 3(a) and FIG. 3(b) indicate a value of the refractive index of a silicon nitride film, and the longitudinal axes show lifetime of minority carriers (in units of micro seconds) in a silicon substrate. Meanwhile, the refractive index of a silicon nitride film that is generally utilized as a passivation film of a semiconductor such as a silicon substrate is about 2."

F "[0039] <<Second passivation film>>

The second passivation film is formed between the first passivation film and the silicon substrate. The second passivation film includes a silicon oxide film and/or an aluminum oxide film as mentioned above. In this regard, however, it is particularly desired that the second passivation film be made of a silicon oxide film only. The reasons of this are as follows. First, among silicon oxide films, a thermally-oxidized film in particular is formed at a high temperature, and, thus, it shows a sufficient passivation effect without changing its properties even in a high temperature process in a fabricating process of a solar cell. On the other hand, an aluminum oxide film is not suitable as a passivation film for an n area, as aluminum contained therein may be introduced as impurities into the silicon substrate and may form a p area."

G "[0047] Furthermore, the refractive indices in FIG. 4 are values measured by the ellipsometry method.

<Method of fabricating a solar cell>

FIG. 5 is a sectional view indicating each step in one aspect of the method of fabricating a solar cell of the present invention. Meanwhile, although, in FIG. 5, only one n+layer and one p+layer are formed on the rear surface of a silicon substrate for the convenience of description, in reality, a plurality of them can be formed. Each of the steps will be described individually in a manner being divided into a group of S1 (step 1)-S7 (step 7) respectively corresponding to FIG. 5(a)-(g) and a group of S9 (step 9) and S10 (step 10) respectively corresponding to FIG. 5(h) and (i). S8 (step 8) will be described referring to FIG. 5(g). Here, in the fabricating method of a solar cell of the present invention, it is necessary to include ‘S7: Forming a passivation film and an anti-reflection film' in particular. In the fabricating method of a solar cell of the present invention, S7 includes a step of forming the second passivation film and a step of forming the first passivation film. Furthermore, in the fabricating method of the present invention, it is preferred to include S1-S6 that are steps of forming a pn junction on the rear surface of a silicon substrate.

[0048] Hereinafter, based on FIG. 5, description will be made on a method of fabricating a solar cell 10.

<<S1: n-type semiconductor substrate>>

As shown in FIG. 5(a), an n-type silicon substrate 1 is prepared. ... (abbreviated)...

[0049] <<S2: Formation of a texture structure of the light-receiving surface>>

As shown in FIG. 5(b), after a texture mask 7 made of a silicon oxide film and the like is formed on the rear surface of the silicon substrate 1 by an atmospheric pressure CVD method and the like, a texture structure 4 is formed on the light-receiving surface of the silicon substrate 1. ...(abbreviated) ...

[0050] <<S3: Formation of an opening of the diffusion mask>>

As shown in FIG. 5(c), a diffusion mask 8 is formed on the light-receiving surface and the rear surface of the silicon substrate 1, and an opening is formed in the diffusion mask 8 on the rear surface. ...

(abbreviated)...

[0051] <<S4: HF cleaning after p-type impurity diffusion>>

As shown in FIG. 5(d), after p-type impurities are diffused, cleaning of the diffusion mask 8 formed in S3 is carried out using hydrogen fluoride (HF) water solution and the like, and thereby a p+layer 5 is formed as a conductivity type impurity diffused layer. ...(abbreviated)...

[0052] <<S5: Formation of an opening of the diffusion mask>>

As shown in FIG. 5(e), the diffusion mask 8 is formed on the light-receiving surface and the rear surface of the silicon substrate 1, and an opening is formed in the diffusion mask 8 on the rear surface. ... (abbreviated)...

[0053] <<S6: HF cleaning after n-type impurity diffusion>>

As shown in FIG. 5(f), after n-type impurities are diffused, the diffusion mask 8 formed in S5 is cleaned by hydrogen fluoride water solution and the like, whereby an n+layer 6 is formed as a conductivity type impurity diffused layer. ...(abbreviated)...

[0054] <<S7: Formation of a passivation film and an anti-reflection film>>

As shown in FIG. 5(g), an anti-reflection film 2 made of a silicon nitride film is formed on the light-receiving surface of the silicon substrate 1, and a passivation film 3

on the rear surface.
[0055] When the passivation film 3 is made of the first passivation film only, the following operation is carried out. First, as the first passivation film, a silicon nitride film having a refractive index of equal to or more than 2.6 is formed on the rear surface of the silicon substrate 1 by a plasma CVD method. On this occasion, adjustment of the refractive index of the first passivation film is carried out using the above-mentioned gas mixture. Next, the anti-reflection film 2 made of a silicon nitride film of a refractive index of 1.9-2.1, for example, is formed on the light-receiving surface of the silicon substrate 1.
[0056] When the passivation film 3 is composed of the first passivation film and the second passivation film, the following operation is carried out. First, on the rear surface of the silicon substrate 1, as the second passivation film, a silicon oxide film, an aluminum oxide film, or a laminated body of a silicon oxide film and an aluminum oxide film is formed. Although a silicon oxide film can be formed by a steam oxidation method, an atmospheric pressure CVD method, and the like, it is preferably formed by a thermal oxidation method, and it is preferred that the processing temperature by the thermal oxidation method be 800-1000 degrees C. The reason of this is that, formation by the thermal oxidation method is a simple method, the properties of a silicon oxide film that is formed are good, and it is dense compared with those of other making methods, resulting in a high passivation effect. It is possible to form an aluminum oxide film by a vapor deposition method, for example.
[0057] Here, when a silicon oxide film is formed on the rear surface of the silicon substrate 1 by the thermal oxidation method, a silicon oxide film is formed also on the light-receiving surface of the silicon substrate 1 at the same time as a result. In such cases, it is preferred that, after protecting the silicon oxide film of the rear surface of the silicon substrate 1, the silicon oxide film formed on the light-receiving surface be removed once entirely by a hydrogen fluoride water solution and the like. Then, on the second passivation film that has been formed, the first passivation film composed of a silicon nitride film of a refractive index of 2.6 or more is formed by the plasma CVD method. An adjustment method of the refractive index of the first passivation film is as described above. Next, the anti-reflection film 2 made of a silicon nitride film of a refractive index of 1.9-2.1, for example, is formed on the light-receiving surface of the silicon substrate 1. The silicon oxide film on the light-receiving surface may be removed after formation of the first passivation film. In addition, it is permissible that the second passivation film be one that includes a film made of a chemical composition other than a silicon oxide film and an aluminum oxide film.

[0058] ...(abbreviated)...

[0059] <<S8: Annealing step>>

In the present invention, it is preferred that, after formation of the passivation film 3 and the anti-reflection film 2, the silicon substrate 1 be annealed. In the present invention, annealing means that the silicon substrate 1 is heat treated. In the annealing in question, it is preferred that heat treatment be performed under an atmosphere including hydrogen and an inactive gas. It is preferred that, in the annealing, the silicon substrate 1 be heat treated at 350-600 degrees C, and, more preferably, at 400-500 degrees C. The reason of this is that, when annealing is carried out at less than 350 degrees C, there is a possibility that annealing effect is not obtained, and when annealing is performed at over 600 degrees C, there is a risk that the passivation film 3 or the anti-reflection film 2 on a surface is destructed (hydrogen in the films is desorbed) to cause degradation of characteristics. In addition, it is preferred that the annealing be carried out for 5 minutes-1 hour, and, more preferably, for 15-30 minutes. When annealing is less than 5 minutes, there is a possibility that annealing effect is not obtained, and when it is over 1 hour, there is a risk that the passivation film 3 or the anti-reflection film 2 on a surface is destructed (hydrogen in the films is desorbed) to cause degradation of characteristics.

[0060]...(abbreviated)...

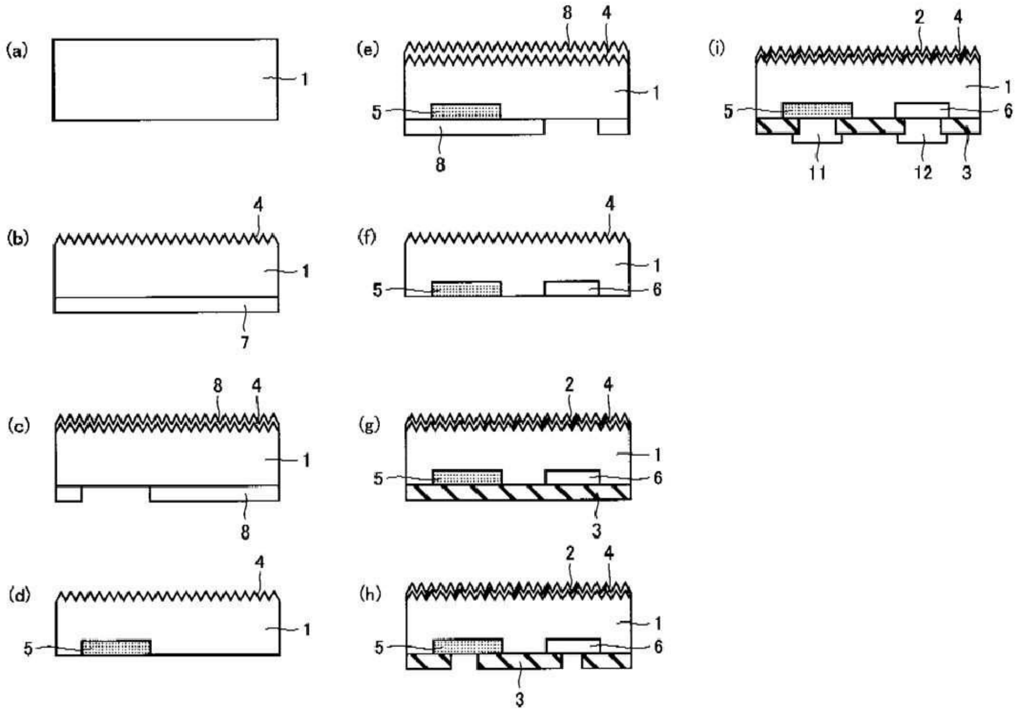
[0061] <<S9: Formation of contact holes>>

As shown in FIG. 5(h), the passivation film 3 on the rear surface of the silicon substrate 1 is partially removed by etching to make part of the p+layer 5 and the n+layer 6 be exposed, and contact holes are fabricated. The contact holes can be fabricated using the above-mentioned etching paste, for example.

[0062] <<S10: Formation of electrodes>>

As shown in FIG. 5(i), a p-electrode 11 and an n-electrode 12 that contact with the exposed surface of the p+layer 5 and the exposed surface of the n+layer 6, respectively, are formed. Such forming method includes screen printing silver paste along the aforementioned contact hole surfaces and then performing burning, for example. By such burning, the p-electrode 11 and the n-electrode 12 that are made of silver and that contact with the silicon substrate 1 are formed. As above, a solar cell of the present invention is completed."

H FIG. 5



(2) Recognition of the Cited Invention

A As seen from the statements described in [0056] ((1) G) that, when "a laminated body of a silicon oxide film and an aluminum oxide film is formed" "on the rear surface of the silicon substrate 1, as the second passivation film," "silicon oxide film" "is preferably formed by a thermal oxidation method", and "It is possible to form an aluminum oxide film by a vapor deposition method, for example," it is recognized that "second passivation film" described in the Cited Document is formed in a manner that, first, the rear surface of a silicon substrate is oxidized by a thermal oxidation method and the like to form "silicon oxide film," and, next, on the "silicon oxide film," "aluminum oxide film" is formed by the "vapor deposition method" and the like.

B In [0059] ((1) G), there is described that "In the present invention, it is preferred that, after formation of the passivation film 3 and the anti-reflection film 2, the silicon substrate 1 be annealed," and, depending on "annealing," "there is a risk that the passivation film 3 or the anti-reflection film 2 on a surface is destructed (hydrogen in the films is desorbed) to cause degradation of characteristics". Therefore, as seen from this, it is recognized that "the passivation film 3" described in the Cited Document is one that is made such that hydrogen in the film does not desorb, that is, one in which dangling bonds are reduced, and thus it includes a chemical passivation film.

C Considering that the "aluminum oxide film" of "the second passivation film," which is formed by "vapor deposition method" and the like, is used as a passivation film, it is obvious that it has a negative fixed charge (if necessary, see the statements of Japanese Unexamined Patent Application Publication No. 2008-10746 cited in the reason for refusal of: "[0042] Next, as shown in FIG. 4(g), dry oxidation (heat oxidization) is performed to the silicon substrate 401 to form a first passivation film 403 made of a silicon oxide film on the whole surface of the rear surface of the silicon substrate 401. ...(abbreviated)... In addition to a silicon oxide film, it is also possible to form an aluminum oxide film having a negative fixed charge by a vapor deposition method and the like as the first passivation film 403. Meanwhile, the first passivation film 403 may be a laminate film formed by a silicon oxide film and an aluminum oxide film and the like."), and thus it can be said that it is a passivation film for electric field effect passivation that directly contacts "silicon oxide film."

D Then, "the passivation film 3," which is a laminated body of "silicon oxide film" and "aluminum oxide film," includes a passivation film for chemical passivation as described above, and "aluminum oxide film" is a passivation film for electric field effect passivation. From this, it can be said that "silicon oxide film" is a passivation film for chemical passivation.

In addition, because "silicon oxide film" and "aluminum oxide film" are of a laminated body, it can be said that they are disposed in a manner one above the other.

E Taking into account the statements of the Cited Document and the above A to D, it is recognized that there is described in the Cited Document

"A solar cell, comprising:

an anti-reflection film 2 formed on a light-receiving surface of an n-type silicon substrate 1 on which a texture structure 4 is formed, the anti-reflection film 2 being made of a silicon nitride film;

a p+layer 5 and an n+layer 6 formed on a rear surface of the silicon substrate 1;

a passivation film 3 including an exposed surface of the p+layer 5 and an exposed surface of the n+layer 6, both exposed surfaces being formed on the rear surface of the silicon substrate 1; and

a p-electrode 11 made of silver and an n-electrode 12 made of silver, the p-electrode 11 and the n-electrode 12 being formed in a manner respectively contacting the exposed surface of the p+layer 5 and the exposed surface of the n+layer 6,

wherein the passivation film 3 comprises:

a second passivation film including a silicon oxide film, the silicon oxide film being a passivation film for chemical passivation formed on the rear surface of the silicon substrate 1, and an aluminum oxide film having a negative fixed charge, the aluminum oxide film being a passivation film for electric field effect passivation formed directly on and in contact with the silicon oxide film, the silicon oxide film and the aluminum oxide film being disposed in a manner one above the other; and

a first passivation film disposed on the second passivation film, the first passivation film made of a silicon nitride film having a refractive index of 2.6 or more." (Hereinafter, referred to as "Cited Invention").

4. Comparison / Judgment

The invention and the Cited Invention will be compared.

"The n-type silicon substrate 1," "light-receiving surface" of "the silicon substrate 1," "rear surface" of "the silicon substrate 1," "a passivation film 3 including an exposed surface of the p+layer 5 and an exposed surface of the n+layer 6, both exposed surfaces being formed on the rear surface of the silicon substrate 1," "a silicon oxide film, the silicon oxide film being a passivation film for chemical passivation formed on the rear surface of the silicon substrate 1," "an aluminum oxide film that is a passivation film for electric field effect passivation formed on the silicon oxide film," and "a first passivation film disposed on the second passivation film, the first passivation film made of a silicon nitride film having a refractive index of 2.6 or more" of the Cited Invention respectively correspond to "semiconductor layer," "front face" of "semiconductor layer," "back face" of "semiconductor layer," "a passivation layer (3) that is useful for passivation of the semiconductor layer surface (20)," "a chemically passivating passivation sub-layer (31)," "a field-effect-passivating passivation sub-layer (33)" made of "aluminum oxide," and "a covering layer made of silicon nitride (SiN_X)" of the Invention.

Furthermore, "the p-electrode 11 made of silver" and "the n-electrode 12 made of silver" of the Cited Invention are in common in a point of "contact metalization."

Then, the Invention and the Cited Invention are identical in a point of "a solar cell, comprising: contact metallization; a semiconductor layer (2); and a passivation layer (3) that is arranged on a surface of the semiconductor layer (2) and is useful for passivating a semiconductor layer surface (20), wherein the passivation layer (3) includes a chemically passivating passivation sub-layer (31) and an field-effect-passivating passivation sub-layer (33) arranged in a manner one above the other in the semiconductor layer surface (20),

wherein the chemically passivating passivation sub-layer (31) directly contacts the field-effect-passivating passivation sub-layer (33), and, wherein

(i) the field-effect-passivating passivation sub-layer (33) comprises aluminum oxide, aluminum fluoride, silicon nitride, aluminium oxynitride, and/or some other compound composed of aluminum oxide and one or more further elements, and

(ii) a covering layer comprising silicon nitride (SiN_X) is attached on the passivation layer," and are different in the following points.

(The different feature)

A point that, about "metallization," the Invention includes "at least front-face-side contact metallization and back-face-side contact metallization," whereas the Cited Invention includes "the p-electrode 11 made of silver" and "the n-electrode 12 made of silver" in the "rear surface" side. In other words, the Invention is of a structure that a pn junction is formed near the light-receiving surface by diffusing impurities that cause a conductivity type opposite the conductivity type of the substrate to the light-receiving surface, and, in conjunction with this, one electrode is disposed on the light-receiving surface, and the other electrode is formed on a surface opposite the light-receiving surface, whereas the Cited Invention is a so called back surface junction solar cell having both of an electrode of one conductivity type and an electrode of the other conductivity type (that is, p-electrode and n-electrode) on the rear surface.

Here, the different feature will now be discussed below.

In alignment of electrodes in a solar cell, ones in which, as is the case with the Cited Invention, a p electrode and an n electrode are provided in the rear surface side without having electrodes in the side of a light-receiving surface, and ones in which electrodes are provided in the light-receiving surface side and the rear surface side are well-known. In addition, even in a solar cell having electrodes provided in the light-receiving surface and the rear surface side, it is well-known to form a passivation film, and there is no difference in the function and structure of a passivation film due to alignment of electrodes. Therefore, it could have been easily conceived of by a person skilled in the art to make the alignment of electrodes of the Cited Invention in which "the p-electrode 11 made of silver" and "the n-electrode 12 made of silver" are provided in the side of the "rear surface" be an alignment in which electrodes are aligned in the light-receiving surface side and the rear surface side.

Then, it could have been easily conceived of by a person skilled in the art to apply the above-mentioned well-known matter to the Cited Invention to make it be the matters specifying the invention of the Invention related to the aforementioned different feature.

5. Closing

As mentioned above, the Invention could be easily invented by a person skilled in the art based on the Cited Invention and the well-known art, and, therefore, the appellant should not be granted a patent for the Invention in accordance with the provisions of Article 29(2) of the Patent Act.

Accordingly, the Invention should be rejected without examining other claims.

Therefore, the appeal decision shall be made as described in the conclusion.

Nov. 9, 2015

Chief administrative judge: ITO, Masaya
Administrative judge: KAWABATA, Osamu
Administrative judge: MATSUKAWA, Naoki