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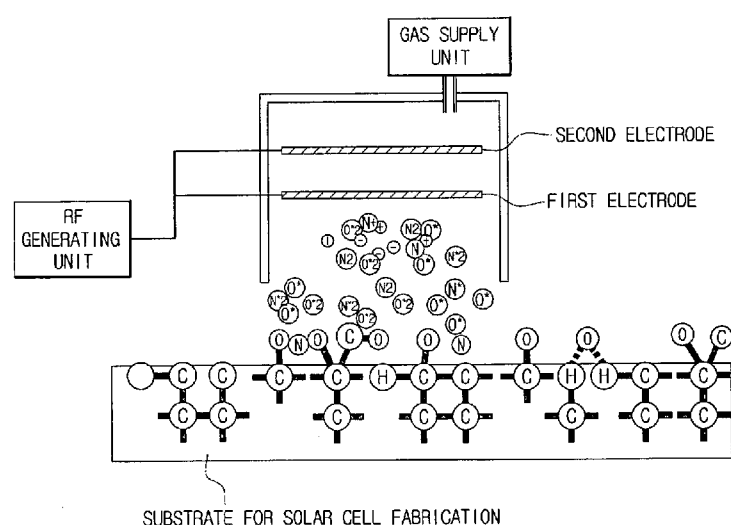
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(54) Title: METHOD FOR SURFACE TREATMENT OF SOLAR CELL

[Figure 2]



(57) Abstract: Disclosed herein is a method for surface treatment of a solar cell. In a method for surface treatment of a solar cell, when the solar cell is fabricated through a series of processes including a preparing process of a substrate for solar cell fabrication, a surface texturing process of the substrate for solar cell fabrication, a forming process of an n-type semiconductor layer and a forming process of front and rear electrodes, a surface of the substrate for solar cell fabrication is cleaned by performing an atmospheric pressure plasma cleaning process with respect to the surface of the substrate for solar cell fabrication before performing the surface texturing process of the substrate for solar cell fabrication so that the surface of the substrate for solar cell fabrication is formed into a hydrophilic surface.

【DESCRIPTION】**【Invention Title】**

METHOD FOR SURFACE TREATMENT OF SOLAR CELL

【Technical Field】

<1> Disclosed herein is a method for surface treatment of a solar cell. More particularly, disclosed herein is a method for surface treatment of a solar cell, which can lower the reflectance of the solar cell and form a uniform n-type semiconductor layer by respectively performing cleaning processes using atmospheric pressure plasma before a texturing process and a forming process of the n-type semiconductor layer.

【Background Art】

<2> Solar cells are core elements of solar photovoltaic power generation, which allow solar light to be directly converted into electric power. A solar cell is a diode basically formed of a p-n junction.

<3> The process in which solar light is converted into electric power by a solar cell will be described. If solar light is incident onto a p-n junction of the solar cell, electron-hole pairs are accumulated. Electrons and holes are respectively moved to an n-layer and a p-type layer by an electric field, so that a photo-electromotive force is generated in the p-n junction. At this time, if a load is applied to both ends of the solar cell or a system is connected to the solar cell, current flows, thereby generating electric power.

<4> Meanwhile, solar cells are variously classified depending on the material and shape of a light-absorbing layer that is a p-n junction layer. The light-absorbing layer may be representative of silicon (Si), and such silicon-based solar cells are classified into a substrate type solar cell and a thin-film type solar cell depending on their shapes. In the substrate type solar cell, a silicon wafer is used as a light-absorbing layer. In the thin-film type solar cell, a light-absorbing layer is formed by depositing silicon in a thin-film shape.

<5> Among these silicon-based solar cells, the structure of the substrate type

solar cell will be described. As shown in FIG. 1, a p-type semiconductor layer 101 and an n-type semiconductor layer 102 are sequentially laminated. A front electrode 103 is formed on the n-type semiconductor layer 102, and a rear electrode 104 is formed beneath the p-type semiconductor layer 101. At this time, the p-type semiconductor layer 101 and the n-type semiconductor layer 102 are formed into one substrate, and upper and lower portions of the substrate are the n-type semiconductor layer 102 and the p-type semiconductor layer 101, respectively. Generally, in the state that a p-type silicon substrate is prepared, n-type impurity ions are doped and diffused in an upper layer portion of the p-type silicon substrate, thereby forming the n-type semiconductor layer 102.

<6> Such silicon-based solar cells are fabricated through processes including a preparing process of a p-type silicon substrate, a surface texturing (irregularity forming) process of the silicon substrate, a doping and diffusing process of n-type impurity ions, a forming process of front and rear electrodes, and the like. At this time, a removing process of an oxide layer, a forming process of an anti-reflection layer, and the like may be further performed before the forming process of the front and rear electrodes.

<7> Meanwhile, main factors that influence on characteristics of silicon-based solar cells are reflectance, diffusion uniformity of n-type impurity ions, and the like. The reflectance means optical reflectance on the surface of a solar cell, and the photoelectric conversion efficiency of the solar cell is enhanced as the reflectance is decreased. The diffusion uniformity of n-type impurity ions refers to a degree to which the n-type impurity ions are uniformly diffused in a p-type silicon substrate in the doping and diffusing process of the n-type impurity ions. When an n-type semiconductor layer is uniformly formed, the photoelectric conversion efficiency is maximized.

<8> Particularly, the forming process of the n-type semiconductor layer is a process in which n-type impurity ions are doped in a substrate by spraying

a solution containing the n-type impurity ions onto the substrate and then diffused in the substrate through a subsequent heat treatment process. Accordingly, it is important to allow the solution containing the n-type impurity ions to be equally spread on the substrate. That is, if the surface of the substrate is formed into a hydrophilic surface, it can be expected that the n-type impurity ions are more equally spread on the substrate. Since the surface texturing process of the silicon substrate is a process of etching the surface of the silicon substrate in an irregular shape using a wet etchant, it is required to perform exact surface etching with respect to the silicon substrate using the wet etchant. Therefore, in order to ensure the precise surface etching, the surface of the silicon substrate is necessarily treated into a hydrophilic surface.

<9> However, conventionally, a preprocessing process for forming the surface of a silicon substrate into a hydrophilic surface is not performed before the texturing process or the forming process of the n-type semiconductor layer is performed. Accordingly, there is a limitation in lowering the reflectance and improving the diffusion uniformity of n-type impurity ions.

【Disclosure】

【Technical Problem】

<10> Disclosed herein is a method for surface treatment of a solar cell, which can lower the reflectance of the solar cell and form a uniform n-type semiconductor layer by respectively performing cleaning processes using atmospheric pressure plasma before a texturing process and a forming process of the n-type semiconductor layer.

【Technical Solution】

<11> In an aspect, there is provided a method of surface treatment of a solar cell, wherein, when the solar cell is fabricated through a series of processes including a preparing process of a substrate for solar cell fabrication, a surface texturing process of the substrate for solar cell fabrication, a forming process of an n-type semiconductor layer and a forming

process of front and rear electrodes, a surface of the substrate for solar cell fabrication is cleaned by performing an atmospheric pressure plasma cleaning process with respect to the surface of the substrate for solar cell fabrication before performing the surface texturing process of the substrate for solar cell fabrication, so that the surface of the substrate for solar cell fabrication is formed into a hydrophilic surface.

<12> In another aspect, there is provided a method of surface treatment of a solar cell, wherein, when the solar cell is fabricated through a series of processes including a preparing process of a substrate for solar cell fabrication, a surface texturing process of the substrate for solar cell fabrication, a forming process of an n-type semiconductor layer and a forming process of front and rear electrodes, a surface of the substrate for solar cell fabrication is cleaned by performing an atmospheric pressure plasma cleaning process with respect to the surface of the substrate for solar cell fabrication before performing the forming process of the n-type semiconductor layer, so that the surface of the substrate for solar cell fabrication is formed into a hydrophilic surface.

<13> The atmospheric pressure plasma cleaning process may include ionizing oxygen into oxygen radicals through a micro-discharge of a compressed air; and reacting the oxygen radicals with organic substances that exist on the substrate for solar cell fabrication and absorbing the oxygen radicals that do not react with the organic substances on the surface of the substrate for solar cell fabrication.

<14> The atmospheric pressure plasma cleaning process may be performed in an atmospheric pressure plasma cleaning apparatus comprising a first electrode, a second electrode, a gas supply unit and a radio frequency (RF) generating unit, and the substrate for solar cell fabrication is mounted at a lower portion of the atmospheric pressure plasma cleaning apparatus. If AC power is applied to the first electrode through the RF generating unit in the state that a compressed air is supplied from the gas supply unit, a micro-discharge may be generated between the first and second electrodes, and the compressed

air that exists between the first and second electrodes may be ionized into radicals (O_2^* , O^* , O^{2*} , O^{*-} , N_2^* , N^* , N^{2*} and N^{*-}) by the micro-discharge.

<15> The substrate for solar cell fabrication may be a silicon substrate.

【Advantageous Effects】

<16> The method of surface treatment of the solar cell has advantages as follows.

<17> The atmospheric pressure plasma cleaning processes are respectively performed before the texturing process and the forming process of the n-type semiconductor layer, thereby enhancing the reflectance characteristic and diffusion uniformity of the solar cell.

【Description of Drawings】

<18> FIG. 1 is a perspective view of a general solar cell.

<19> FIG. 2 is a reference diagram illustrating an atmospheric pressure plasma cleaning process according to an embodiment.

<20> FIG. 3 is a reference diagram illustrating oxygen radicals absorbed on a substrate through reaction between the oxygen radicals and organic substances.

<21> FIG. 4 is a graph showing contents of carbons before and after the atmospheric pressure plasma cleaning process is performed according to the embodiment.

<22> FIGS. 5 and 6 are photographs respectively showing contact characteristics when the atmospheric pressure plasma cleaning process is performed with respect to a substrate for solar cell fabrication before a texturing process and when the atmospheric pressure plasma cleaning process is not performed with respect to the substrate for solar cell fabrication before the texturing process.

<23> FIGS. 7 and 8 are photographs respectively showing contact characteristics when the atmospheric pressure plasma cleaning process is performed with respect to the substrate for solar cell fabrication before a diffusing process and when the atmospheric pressure plasma cleaning process

is not performed with respect to the substrate for solar cell fabrication before the diffusing process.

<24> FIG. 9 is a graph showing reflectances when the atmospheric pressure plasma cleaning process is performed (AP+intex) before the texturing process and when the atmospheric pressure plasma cleaning process is not performed (intex) before the texturing process.

<25> FIGS. 10 and 11 are graphs showing sheet resistances (R_{sheet}) of the substrate for solar cell fabrication in the state that a forming process of an n-type semiconductor layer is completed.

【Mode for Invention】

<26> Exemplary embodiments now will be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments are shown. This disclosure may, however, be embodied in many different forms and should not be construed as limited to the exemplary embodiments set forth therein. Rather, these exemplary embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of this disclosure to those skilled in the art. In the description, details of well-known features and techniques may be omitted to avoid unnecessarily obscuring the presented embodiments.

<27> The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of this disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. Furthermore, the use of the terms a, an, etc. does not denote a limitation of quantity, but rather denotes the presence of at least one of the referenced item. The use of the terms "first", "second", and the like does not imply any particular order, but they are included to identify individual elements. Moreover, the use of the terms first, second, etc. does not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. It will be further understood that the terms "comprises" and/or "comprising" or "includes" and/or "including" when

used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

<28> Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

<29> In the drawings, like reference numerals in the drawings denote like elements. The shape, size and regions, and the like, of the drawing may be exaggerated for clarity.

<30> In a method for surface treatment of a solar cell according to an embodiment, when performing fabrication processes, i.e., a series of processes including a preparing process of a substrate for solar cell fabrication, a surface texturing process of the substrate for solar cell fabrication, a forming process of an n-type semiconductor layer and a forming process of front and rear electrodes, a surface of the substrate for solar cell fabrication is cleaned using atmospheric pressure plasma before respectively performing the surface texturing process of the substrate for solar cell fabrication and the forming process of the n-type semiconductor layer. At this time, a silicon substrate or another substrate may be used as the substrate for solar cell fabrication.

<31> Also, in the method for surface treatment of the solar cell, the substrate for solar cell fabrication is formed into a hydrophilic surface through an atmospheric pressure plasma cleaning process, so that the contact property of the substrate for solar cell fabrication is improved when respectively performing the surface texturing process of the substrate for solar cell fabrication and the forming process of the n-type semiconductor

layer.

<32> The surface texturing process of the substrate for solar cell fabrication is a process in which an irregular shape is formed on the surface of the substrate for solar cell fabrication using a wet etchant so as to minimize reflection of light. The atmospheric pressure plasma cleaning process is performed before the surface texturing process of the silicon substrate, thereby improving the contact property between the surface of the substrate for solar cell fabrication and the wet etchant.

<33> The forming process of the n-type semiconductor layer is a process of forming the n-type semiconductor layer on the substrate for solar cell fabrication by spraying a solution of phosphoric acid and ethanol onto the surface of the substrate for solar cell fabrication and diffusing n-type impurity ions in the substrate for solar cell fabrication through a subsequent heat treatment process. The atmospheric pressure plasma cleaning process is performed before the forming process of the n-type semiconductor layer, thereby improving the contact property between the surface of the substrate for solar cell fabrication and the solution containing the n-type impurity ions.

<34> Meanwhile, the surface of the substrate for solar cell fabrication can be formed into a hydrophilic surface through reaction with oxygen radicals sprayed onto the surface of the substrate for solar cell fabrication. The hydrophilic surface of the substrate for solar cell fabrication can be formed through the atmospheric pressure plasma cleaning process.

<35> The atmospheric pressure plasma cleaning process and the forming process of the surface of the substrate for solar cell fabrication into the hydrophilic surface, performed in the method disclosed herein, will be described in detail with reference to the accompanying drawings. FIG. 2 is a reference diagram illustrating an atmospheric pressure plasma cleaning process according to an embodiment. FIG. 3 is a reference diagram illustrating oxygen radicals absorbed on a substrate through reaction between the oxygen radicals and organic substances.

<36> As illustrated in FIG. 2, an atmospheric pressure plasma cleaning apparatus according to the embodiment includes a first electrode, a second electrode, a gas supply unit and a radio frequency (RF) generating unit. The first and second electrodes may be formed of a metal electrode and a ceramic electrode, respectively. The gas supply unit functions to supply compressed dry air (CDA), and the RF generating unit functions to apply AC power to the first electrode. A substrate for solar cell fabrication is mounted at a lower portion of the atmospheric pressure plasma cleansing apparatus.

<37> Under the configuration described above, if AC power is applied to the first electrode through the RF generating unit in the state that a compressed air is supplied from the gas supply unit, a micro-discharge is generated between the first and second electrodes, and the compressed air, i.e., nitrogen (N_2) and oxygen (O_2), that exists between the first and second electrodes, is ionized into various types of radicals (O_2^* , O^* , O^{2-*} , O^- , N_2^* , N^* , N^{2-*} and N^{-*}) by the micro-discharge.

<38> As illustrated in FIG. 3, oxygen radicals (O_2^* , O^* , O^{2-*} and O^-) are chemically bonded to organic substances through reaction with the organic substances that exist on a surface of the substrate for solar cell fabrication. Therefore, the oxygen radicals are changed into solid-state or vapor-phase compounds. The solid-state compounds may be removed through a subsequent wet or dry cleaning process. Oxygen radicals that do not react with the organic substances are absorbed on the surface for solar cell fabrication so as to forming the surface of the substrate for solar cell fabrication into a hydrophilic state.

<39> As such, the formation of the surface of the substrate for solar cell fabrication in the hydrophilic state means that when a liquid is coated on the substrate for solar cell fabrication, a wetting angle is decreased. Accordingly, a wet etchant can be equally coated on the substrate for solar cell fabrication in a surface texturing process of the substrate for solar

cell fabrication, and a solution containing n-type impurity ions can be equally coated on the substrate for solar cell fabrication in a forming process of an n-type semiconductor layer.

<40> Hereinafter, experimental results obtained by applying the method for surface treatment of the solar cell according to the embodiment will be described.

<41> FIG. 4 is a graph showing contents of carbons before and after the atmospheric pressure plasma cleaning process is performed according to the embodiment. As shown in FIG. 4, it can be seen that on the surface of the substrate for solar cell fabrication, the content of carbons is about 70% before the atmospheric pressure plasma cleaning process, and the content of carbons is decreased to about 30% as the atmospheric pressure plasma cleaning process is performed. Also, it can be seen that in the interior of the substrate for solar cell fabrication, the content of carbons is rapidly decreased as the atmospheric pressure plasma cleaning process is performed.

<42> FIGS. 5 and 6 are photographs respectively showing contact characteristics when the atmospheric pressure plasma cleaning process is performed with respect to the substrate for solar cell fabrication before a texturing process and when the atmospheric pressure plasma cleaning process is not performed with respect to the substrate for solar cell fabrication before the texturing process. FIGS. 7 and 8 are photographs respectively showing contact characteristics when the atmospheric pressure plasma cleaning process is performed with respect to the substrate for solar cell fabrication before a diffusing process and when the atmospheric pressure plasma cleaning process is not performed with respect to the substrate for solar cell fabrication before the diffusing process. As shown in FIGS. 5, 6, 7 and 8, it can be seen that as the atmospheric pressure plasma cleaning process according to the embodiment is performed, the wetting angle between the solution and the substrate for solar cell fabrication is remarkably decreased, and therefore, the solution is equally coated on the substrate for solar cell fabrication.

<43> FIG. 9 is a graph showing reflectances when the atmospheric pressure plasma cleaning process is performed (AP+intex) before the texturing process and when the atmospheric pressure plasma cleaning process is not performed (intex) before the texturing process. The experimental result of FIG. 9 shows a value obtained by averaging reflectances for 15 substrates for solar cell fabrication. As shown in FIG. 9, the reflectance is 22.37% on average when the atmospheric pressure plasma cleaning process is not performed, and the reflectance is 21.25% on average after the atmospheric pressure plasma cleaning process is performed. Therefore, it can be seen that the reflectance characteristic is improved.

<44> FIGS. 10 and 11 are graphs showing sheet resistances (R_{sheet}) of the substrate for solar cell fabrication in the state that a process of forming an n-type semiconductor layer is completed. The experimental result of FIG. 10 shows a value obtained by measuring sheet resistances at 25 points in a sheet of substrate for solar cell fabrication and calculating a standard deviation for the sheet resistances. The experimental result of FIG. 10 shows a value obtained by measuring sheet resistances for 15 sheets of sample substrate for solar cell fabrication and averaging the sheet resistances. As shown in FIG. 10 and the following <Table 1>, the standard deviation of sheet resistances is 1.51 when the atmospheric pressure plasma cleaning process is performed (AP+Diffusion), and the standard deviation of sheet resistances is 2.2 when the atmospheric pressure plasma cleaning process is not performed (Diffusion). Therefore, it can be seen that the uniformity of sheet resistances is improved by performing the atmospheric pressure plasma cleaning process, and accordingly, the diffusion uniformity of the n-type semiconductor layer is enhanced.

<45> The experimental result of FIG. 11 shows a value obtained by measuring difference values between maximum and minimum sheet resistance (Max-Min) for 15 sheets of substrate for solar cell fabrication and averaging the difference values. As shown in FIG. 11 and the following <Table 1>, the difference value between maximum and minimum sheet resistances is 6.31 when

the atmospheric pressure plasma cleaning process is performed (AP+Diffusion), and the difference value between maximum and minimum sheet resistances is 9.57 when the atmospheric pressure plasma cleaning process is not performed (Diffusion). Therefore, it can be seen that the diffusion uniformity of the n-type semiconductor layer is enhanced after the atmospheric pressure plasma cleaning process is performed.

<46> <Table 1>

<47>

	Standard Deviation (Average)	Max-Min (Average)
Diffusion	2.2	9.57
AP + Diffusion	1.51	6.31

<48>

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

【CLAIMS】

【Claim 1】 A method for surface treatment of a solar cell, wherein, when the solar cell is fabricated through a series of processes including a preparing process of a substrate for solar cell fabrication, a surface texturing process of the substrate for solar cell fabrication, a forming process of an n-type semiconductor layer and a forming process of front and rear electrodes,

<51> a surface of the substrate for solar cell fabrication is cleaned by performing an atmospheric pressure plasma cleaning process with respect to the surface of the substrate for solar cell fabrication before performing the surface texturing process of the substrate for solar cell fabrication, so that the surface of the substrate for solar cell fabrication is formed into a hydrophilic surface.

【Claim 2】 A method for surface treatment of a solar cell, wherein when the solar cell is fabricated through a series of processes including a preparing process of a substrate for solar cell fabrication, a surface texturing process of the substrate for solar cell fabrication, a forming process of an n-type semiconductor layer and a forming process of front and rear electrodes,

<53> a surface of the substrate for solar cell fabrication is cleaned by performing an atmospheric pressure plasma cleaning process with respect to the surface of the substrate for solar cell fabrication before performing the forming process of the n-type semiconductor layer, so that the surface of the substrate for solar cell fabrication is formed into a hydrophilic surface.

【Claim 3】 The method according to claim 1 or 2, wherein the atmospheric pressure plasma cleaning process comprises:

<55> ionizing oxygen into oxygen radicals through a micro-discharge of a compressed air; and

<56> reacting the oxygen radicals with organic substances that exist on the substrate for solar cell fabrication and absorbing the oxygen radicals that do not react with the organic substances on the surface of the substrate for

solar cell fabrication.

【Claim 4】 The method according to claim 1 or 2, wherein:

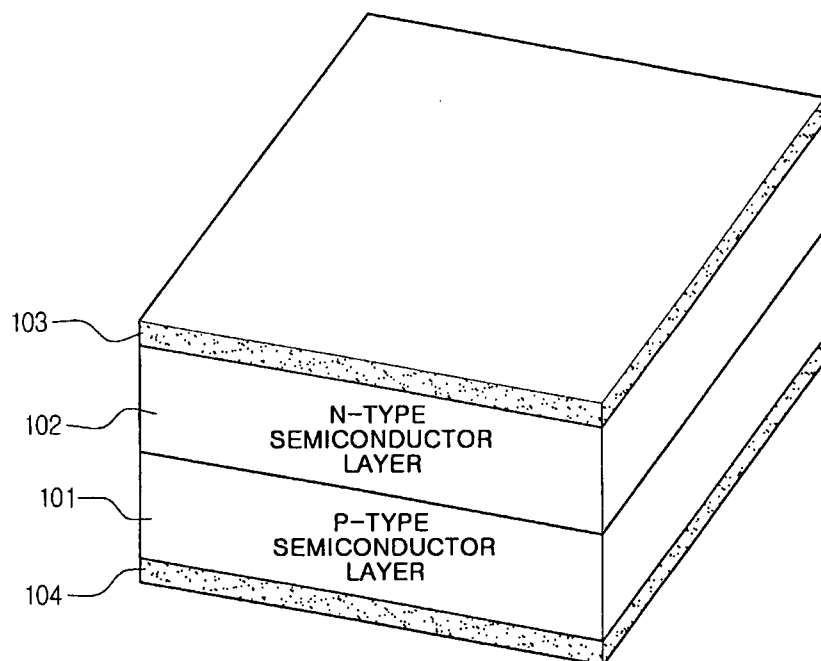
<57> the atmospheric pressure plasma cleaning process is performed in an atmospheric pressure plasma cleaning apparatus comprising a first electrode, a second electrode, a gas supply unit and a radio frequency (RF) generating unit, and the substrate for solar cell fabrication is mounted at a lower portion of the atmospheric pressure plasma cleaning apparatus; and

<58> if AC power is applied to the first electrode through the RF generating unit in the state that a compressed air is supplied from the gas supply unit, a micro-discharge is generated between the first and second electrodes, and the compressed air that exists between the first and second electrodes is ionized into radicals (O_2^* , O^* , O^{2-*} , O^- , N_2^* , N^* , N^{2-*} and N^-) by the micro-discharge.

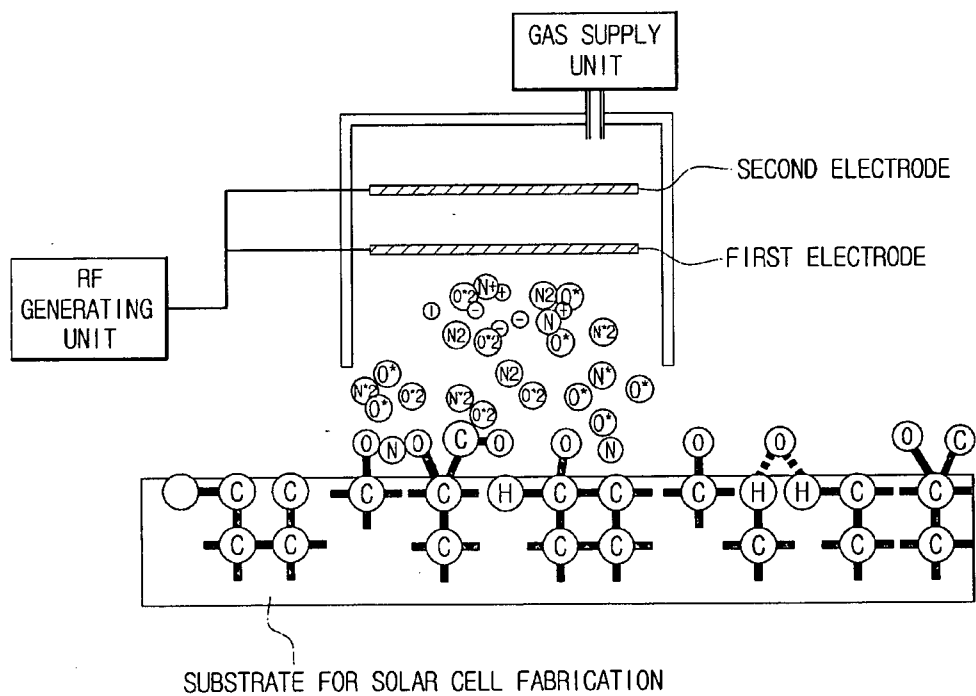
【Claim 5】 The method according to claim 1 or 2, wherein the substrate for solar cell fabrication is a silicon substrate.

【DRAWINGS】

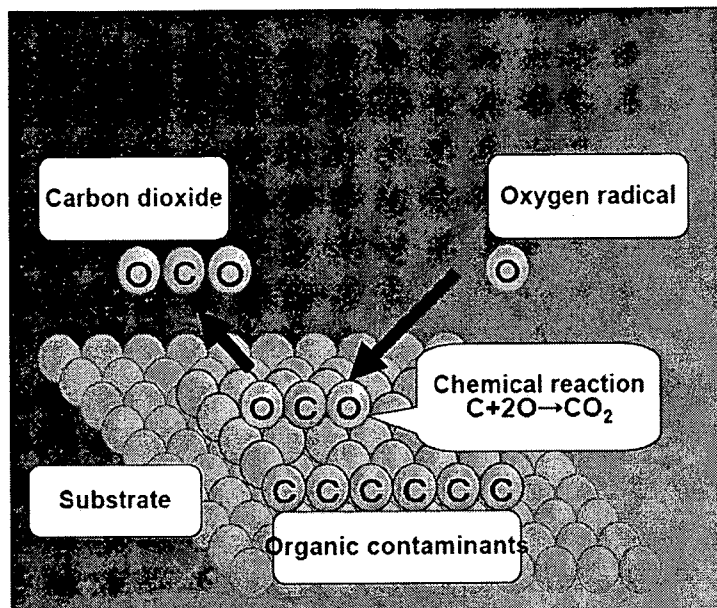
【Figure 1】



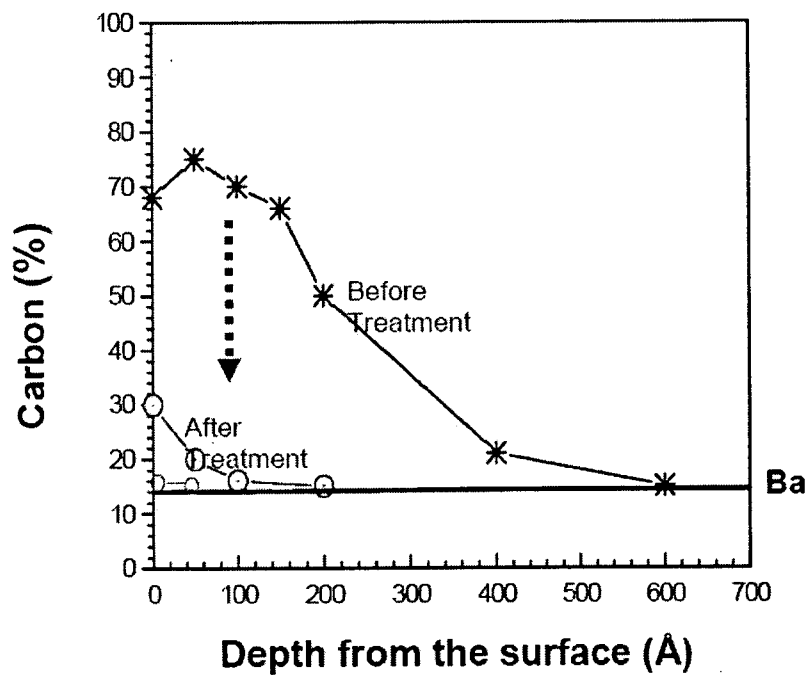
【Figure 2】



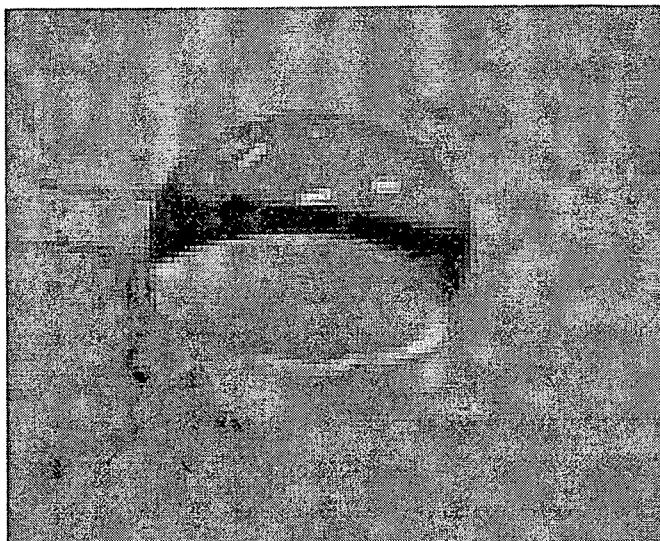
【Figure 3】



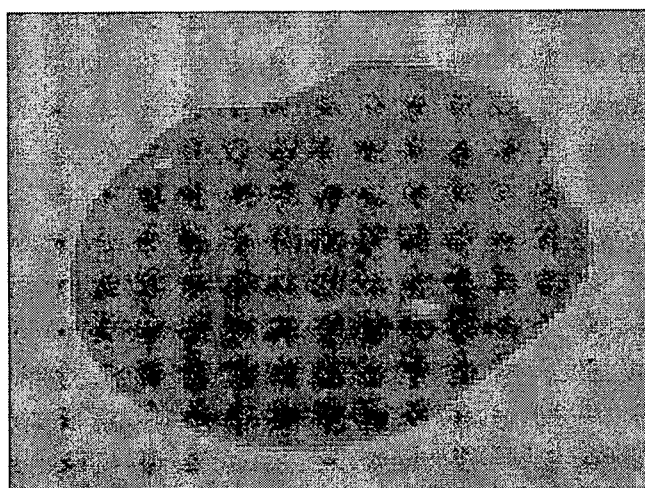
【Figure 4】



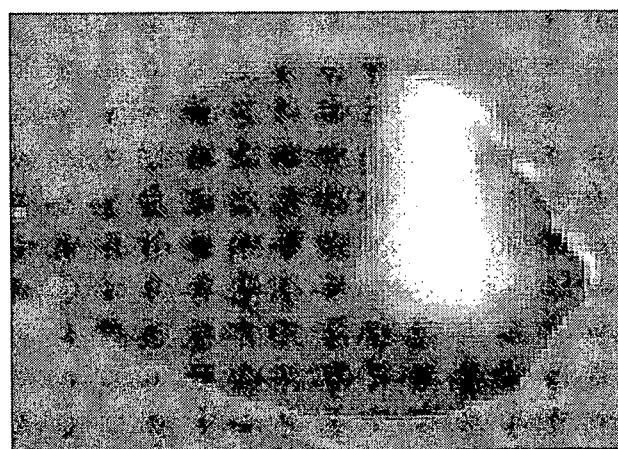
【Figure 5】



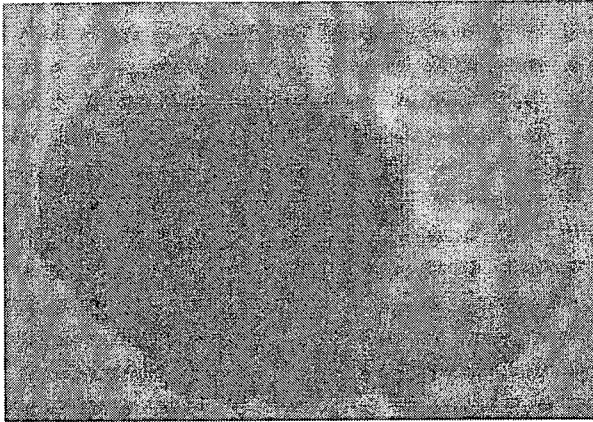
【Figure 6】



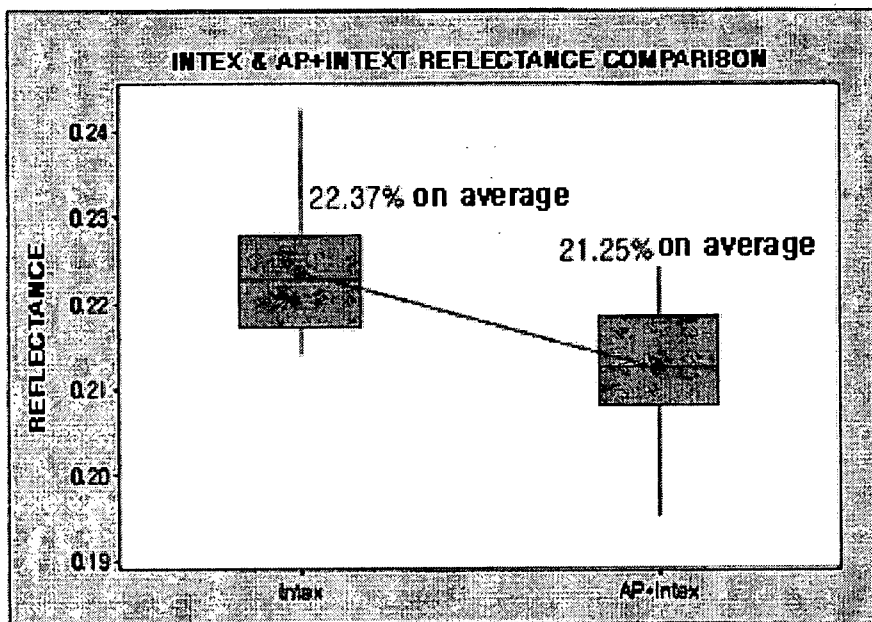
【Figure 7】



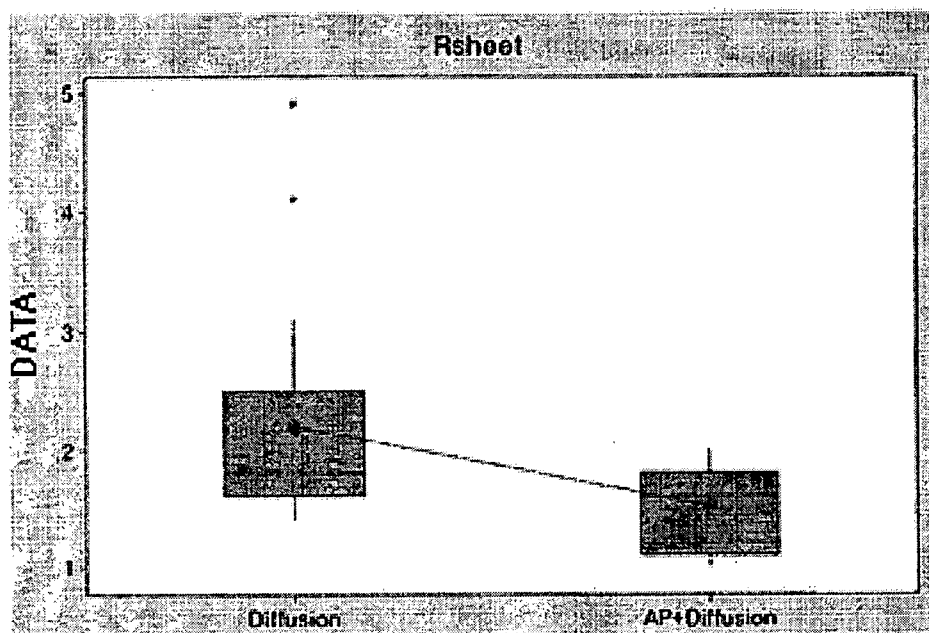
【Figure 8】



【Figure 9】



【Figure 10】



【Figure 11】

