

(51) International Patent Classification:
H01L 31/042 (2006.01)(21) International Application Number:
PCT/KR2008/006618(22) International Filing Date:
10 November 2008 (10.11.2008)

(25) Filing Language: Korean

(26) Publication Language: English

(30) Priority Data:
10-2008-0078416 11 August 2008 (11.08.2008) KR(71) Applicant (for all designated States except US): **KOREA RESEARCH INSTITUTE OF STANDARDS AND SCIENCE** [KR/KR]; 1 Doryong-dong, Yuseong-gu, Daejeon, 305-340 (KR).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **KIM, Kyung Joong** [KR/KR]; #6-102, Gongdongwanri Apt., 431, Doryong-dong, Yuseong-gu, Daejeon, 305-340 (KR). **LEE, Woo** [KR/KR]; #110-1504, Hanwha Apt., Gwanpyeong-dong, Yuseong-gu, Daejeon, 305-509 (KR).(74) Agents: **KWON, Oh-Sig** et al.; 4F, Joeeunleaderstel, 921 Dunsan-dong, Seo-gu, Daejeon, 302-120 (KR).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

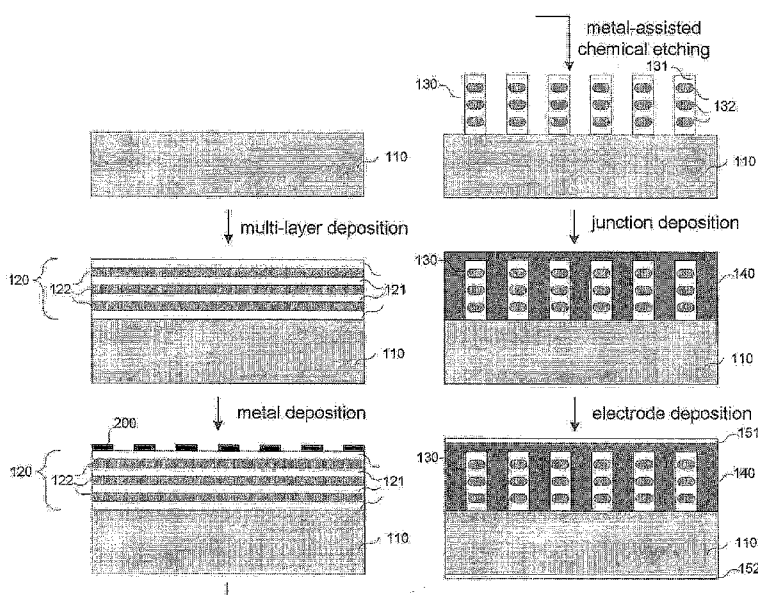
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- with amended claims and statement (Art. 19(1))

(54) Title: SOLAR CELL HAVING QUANTUM DOT NANOWIRE ARRAY AND THE FABRICATION METHOD THERE-OF

【Figure 1】



(57) Abstract: The present invention relates to a solar cell having quantum dot nanowire array and the fabrication method thereof. The solar cell according to the present invention includes quantum dot nanowire array with a heterostructure including matrix and semiconductor quantum dots, and p-type and n-type semiconductor and electrodes each contacting the quantum dot nanowires. With the solar cell according to the present invention, the band gap energy of the semiconductor quantum dot can be easily controlled, the semiconductor quantum dots having different sizes are provided in the quantum dot nanowire so that the photoelectric conversion can be performed in the wide spectrum from visible rays to infrared rays, the quantum dot is embedded in the high density quantum dot nanowire array so that light absorption can be maximized, and the quantum dot nanowire contact p-type and n-type semiconductor over a wide area, conduction efficiency of electrons and holes can be improved.

【DESCRIPTION】**【Invention Title】**

SOLAR CELL HAVING QUANTUM DOT NANOWIRE ARRAY AND THE
FABRICATION METHOD THEREOF

5

【Technical Field】

The present invention relates to a solar cell having
quantum dot nanowire array and the fabricating method thereof,
and more particularly to a solar cell having quantum dot
10 nanowire array in which semiconductor quantum dots are
internally embedded, and the fabrication method thereof.

【Background Art】

Since the Kyoto protocol aiming at resulting carbon
15 dioxide (CO₂) emission, which are thought to contribute the
global warming, had been adopted as of December, 1997, studies
on renewable and clean alternative energy sources such as
solar energy, wind power, and water power, have been actively
developed in order to reduce a great quantity of carbon
20 dioxide (CO₂).

A photovoltaic device (solar cell), which is spotlighted
as clean alternative energy, means a device to generate
current-voltage using photovoltaic effects that a
semiconductor absorbs light to generate electrons and holes.

An n-p diode of inorganic semiconductor material such as silicon or gallium arsenide (GaAs), whose stability and efficiency have been proved, has been mainly used, however, a high manufacturing cost thereof has been an obstacle in substantial utilization of a solar cell.

Although cheaper solar cells using dye-sensitized material and organic/polymeric material have been actively developed, the market share of them is very low to around 3% compared to the silicon based solar cells due to a very low efficiency and a short life span by deterioration.

Although most of the photovoltaic devices use single crystal silicon and poly crystal silicon, the cost occupied by silicon material and wafer to construct a solar system exceeds 40% of the entire construction cost, and thus, there have been efforts to reduce the amount of silicon required in producing unit power through structural (morphology) or physical (bandgap engineering) approach and to minimize silicon consumption through a thin film device.

20 **【Disclosure】**

【Technical Problem】

 The object of the present invention is to provide a solar cell capable of performing a photoelectric conversion in a wide spectrum from visible to infrared lights, maximizing

light absorption through bandgap engineering of material, and improving conductive efficiency of electrons and holes generated by absorbing light. Another object of the present invention is to provide a simple and economic fabricating method of a high efficiency solar cell with controllable band gap energy and a light absorbing layer where a photoelectric conversion is performed has a large specific surface area

【Technical Solution】

To achieve the above object, the present invention provides a fabrication method of a solar cell having quantum dot nanowire array comprising:

a) fabricating a multilayer by repeatedly stacking matrix layers formed of semiconductor nitride or semiconductor oxide, and semiconductor layers on an upper part of a semiconductor substrate doped with p-type or n-type impurities; b) fabricating a quantum dot nanowire array constituted by a plurality of quantum dot nanowires whose one ends are fixed on the semiconductor substrate and are spaced from each other to be vertically arranged by partially etching the multilayer vertically to the semiconductor substrate and; c) depositing a semiconductor doped with the opposite-type impurities to impurities of the semiconductor substrate on the upper part of the semiconductor substrate formed with the quantum dot

nanowire array and filling at least empty spaces between the other ends of the quantum dot nanowires and the semiconductor substrate with the semiconductor doped with opposite-type impurities; and d) forming a lower electrode on a lower part of the semiconductor substrate, and forming an upper electrode on an upper part surface formed with the quantum dot nanowire array and semiconductor surface doped with the opposite-type impurities or on an upper part of semiconductor surface doped with the opposite-type impurities so that the upper electrode corresponds to the lower electrode.

The fabrication method of a solar cell having quantum dot nanowire array in particular comprising: a) fabricating a multilayer film with alternating silicon nitride (or silicon oxide) layers and semiconductor layers on a semiconductor substrate doped with p-type or n-type impurities ;b) fabricating a quantum dot nanowire array whose one ends are fixed on the semiconductor substrate and are spaced from each other to be vertically arranged by partial etching the multiple stacked layers vertically to the semiconductor substrate and; c) filling the empty spaces between the other ends of the quantum dot nanowires and the semiconductor substrate with the semiconductor doped with opposite-type impurities; and d) forming a lower electrode on a lower part of the semiconductor substrate, and forming an upper electrode

on a upper part surface formed with the quantum dot nanowire array.

The multilayer of a) step may be fabricated through a deposition process using a PVD or a CVD, the semiconductor
5 layer and the matrix layer constituting the multilayer may have thickness less than 10 nm, independently from each other, the plurality of semiconductor layers constituting the multilayer may have different thickness, and the thickness of the respective semiconductor layers may be less than 10nm,
10 independently from each other.

The step b) may comprise: b1-1) depositing Ag, Au or a catalyst metal that is a transition metal on the upper part of the multilayer in a mesh type; and b1-2) performing a wet etching using mixed aqueous solution containing hydrofluoric
15 acid and aqueous hydrogen peroxide.

The step b) may further comprises: b2-1) forming circular metal nano dot array on the upper part of the quantum dot multilayer; and

b2-2) performing a reactive ion etching (RIE) using the
20 metal nano dots as masks.

At this time, a composite nanowire shape in which the nano disc-shaped matrix and nano disc-shaped semiconductors are repeatedly coupled in sequence is fabricated by the etching (wet etching or reactive ion etching) of the step b),

and the surface of the nano disc shaped semiconductor is naturally oxidized during or after the etching process.

Quantum dot nanowires whose semiconductor quantum dots are embedded in the matrix are fabricated by the etching of
5 the step b), the size of the semiconductor quantum dots is controlled by the thickness of each semiconductor layers constituting the multilayer, and a light absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot constituting the quantum dot
10 nanowire or the combination thereof.

The step c) may be the deposition using a CVD or a PVD.

The semiconductor substrate may be a p-type (or an n-type) silicon substrate, the semiconductor doped with the opposite-type impurities is an n-type (or a p-type) silicon,
15 the matrix is silicon oxide or silicon nitride, and the semiconductor layers of the multilayer is silicon.

The present invention provides a solar cell having quantum dot nanowire array fabricated using the fabrication method as described above, comprising:

20 a lower electrode; a first semiconductor layer formed on the upper part of the lower electrode and doped with n-type (or p-type) impurities; a second semiconductor layer formed over the first semiconductor layer and doped with opposite-type impurities to the first semiconductor layer; an upper

electrode formed on an upper part of the semiconductor layer;
and a quantum dot nanowire array constituted by a plurality of
quantum dot nanowires vertically arranged in the second
semiconductor layer to be spaced from each other, wherein the
5 quantum dot nanowire that constitutes the quantum dot nanowire
array, whose one end contacts the first semiconductor layer,
includes matrix and at least one semiconductor quantum dots
surrounded by the matrix.

At this time, the other ends of the quantum dot nanowires
10 are present on the surface of the second semiconductor layer
so that the other ends may contact the upper electrode or the
other ends of the quantum dot nanowires are present in the
second semiconductor layer so that the quantum dot nanowires
may be embedded in the second semiconductor layer.

15 The first semiconductor layer and the second
semiconductor layer may have the same semiconductive
substances doped with impurities having different nature (p-
type or n-type), and the matrix may be semiconductor nitride,
semiconductor oxide or a mixture of them. More preferably, the
20 semiconductor nitride or the semiconductor is same as the
semiconductor substances constituting the first semiconductor
layer and the second semiconductor layer.

The quantum dot nanowire that constitutes the quantum dot
nanowire array has two or more semiconductor quantum dots

arranged vertically to the quantum dot nanowires, and the semiconductor quantum dots included in the quantum dot nanowires may be fabricated to have the same or different size.

The quantum dot nanowires may be composed of
5 semiconductor quantum dots with diameter of less than 10 nm.

With the solar cell according to the present invention, the wavelength of the light absorption may be controlled by means of the sort of the matrix, the size of the semiconductor quantum dot or the combination thereof.

10 The first semiconductor layer is a silicon layer, the second semiconductor layer is a silicon layer, the matrix is silicon oxide, silicon nitride or a mixture thereof, and the semiconductor quantum dot is a silicon quantum dot.

15 **【Advantageous Effects】**

The solar cell according to the present invention includes quantum dot nanowire array with a heterostructure including matrix and semiconductor quantum dots, and p-type and n-type semiconductor and electrodes each contacting the
20 quantum dot nanowires. With the solar cell according to the present invention, the band gap energy of the semiconductor quantum dot can be easily controlled, the semiconductor quantum dots having different sizes are provided in the quantum dot nanowire so that the photoelectric conversion can

be taken place in a wide spectrum from visible rays to infrared rays, the quantum dots are embedded in the high density quantum dot nanowire arrays so that light absorption can be maximized, and the quantum dot nanowire contact p-type and n-type semiconductor over a large area, conduction efficiency of electrons and holes can be improved. The fabrication method according to the present invention forms a stacked thin film in which matrix layers and semiconductor layers having the thickness of several nanometers and then etches the stacked thin film, thereby fabricating quantum dot nanowire array formed with semiconductor quantum dots.

Therefore, with the fabrication method according to the present invention, a high efficiency solar cell can be fabricated through a simple and economical process, the wavelength of the absorbing light can be easily controlled by controlling the thickness of the semiconductor layer of the stacked thin film, the sort of matrix, and the contracted diameter of the quantum dot nanowire, etc., and a pair of electron/hole can be generated by absorbing light in a wide spectral region from infrared rays to visible rays.

【Description of Drawings】

The above and other objects, features and advantages of the present invention will become apparent from the following

description of preferred embodiments given in conjunction with the accompanying drawings, in which:

FIG. 1 is an example of a process view showing a fabricating method of a solar cell according to the present invention;

FIG. 2 is an example of a process view fabricating a quantum dot nanowire array in a fabricating method of a solar cell according to the present invention;

FIG. 3 is another example of a process view fabricating a quantum dot nanowire array in a fabricating method of a solar cell according to the present invention;

FIG. 4 is an example of a process view showing a step of forming unevenness by RIE in a fabricating method of a solar cell according to the present invention;

FIG. 5 is another example of a process view fabricating a quantum dot nanowire array in a fabricating method of a solar cell according to the present invention; and

FIG. 6 is an example showing a structure of a solar cell according to the present invention.

[Detailed Description of Main Elements]

110: p-type semiconductor	120: multilayer
121: matrix layer	122: semiconductor layer
120': multilayer with surface unevenness	
130: quantum dot nanowire	131: matrix

132: semiconductor quantum dot 140: n-type semiconductor

151, 152: electrodes

200: metal mesh

210: circular metal dot

300: nanoporous anodic alumina

5

【Best Mode】

Hereinafter, a solar cell having quantum dot nanowire array and the fabrication method thereof according to the present invention will be described in detail with reference
10 to the accompanying drawings. The drawings set forth herein are provided so that those skilled in the art can fully understand the present invention. Therefore, the present invention may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Like
15 reference numerals refer to like elements throughout.

At this time, if there are no specific definitions in technical and scientific terminologies used herein, the terminologies have meanings that are commonly understood by those skilled in the art to which the present invention
20 pertains. In the following description and the accompanying drawings, if it is judged that the specific explanation on the related well-known function or constitution may make the gist of the present invention obscure, the detailed explanation thereof will be omitted.

FIG. 1 is an example of a process view showing a fabricating method of a solar cell according to the present invention. Referring to FIG. 1, a multilayer 120 is fabricated on an upper part of a p-type semiconductor layer 110 by alternately depositing a matrix thin film (matrix layer, 121) and a semiconductor thin film (semiconductor layer, 122) using a deposition process, and then quantum dot nanowire 130 array is fabricated in a top-down method that the fabricated multilayer 120 is partially etched in a direction vertical to a surface of the p-type semiconductor layer 110.

At the time of deposition, preferably, the thicknesses of the matrix thin film 121 and the semiconductor thin film 122 are deposited to be nanometer order, respectively, and more preferably, the thickness of the matrix thin film 121 and the semiconductor thin film 122 is deposited to be less than 10 nm, independently from each other.

The matrix thin film 121 is formed of semiconductor oxide, semiconductor nitride, or a mixture thereof. A plurality of matrix thin films 121 constituting the multilayer may have a different substance (semiconductor oxide, semiconductor nitride and a mixture of the semiconductor oxide and semiconductor nitride) and a different thickness for each film.

The quantum dot nanowire 130 according to the present invention is fabricated by partial etching of the multilayer

120, such that it is characterized in that a crystalline or amorphous matrix 131 and a crystalline or amorphous semiconductor 132 constituting the multilayer 120 are mixed with a hetero interface with each other, and has a structure
5 that the crystalline or amorphous semiconductor 132 is embedded in the nanowire in a quantum dot shape.

This means that during or after the etching process for fabricating the quantum dot nanowire 130 array, a surface native oxide of the semiconductor 132 exposed to the surface
10 by the etching is induced to allow the semiconductor constituting the quantum dot nanowire 130 to be embedded in the nanowire in a quantum dot shape.

As described above, the quantum dot nanowire 130 array according to the present invention is characterized by
15 fabricating the quantum dot nanowire 130 array in a top-down method by means of the partial etching of the multilayer 120 rather than by a bottom-up method such as a VLS growth method using noble metal catalysts. Accordingly, the quantum dot nanowire 130 can be formed in a direction vertical to the p-
20 type semiconductor layer, regardless of substances, crystallinity, and crystalline direction of surface, etc. of the p-type semiconductor layer attached with nanowires, wherein a plurality of quantum dot nanowires 130 are regularly arranged, with high density.

The quantum dot nanowire 130 are fabricated by partially etching the multilayer 120 so that the quantum dot nanowire 130 has a structure where two or more embedded quantum dots 132 are arranged vertically to the major axis of the nanowire.

5 Although semiconductor films 122 having the same thickness are shown in FIG. 1, size of the quantum dots 132 arranged in a major axis direction of the quantum dot nanowire 130 can be controlled to be different by controlling the thickness of the semiconductor films 122 constituting the
10 multilayer 120 to be different.

More specifically, the quantum dot nanowire 130 and the array thereof are fabricated in the top-down method using the etching method, such that the length of the major axis of the quantum dot nanowire 130 can be controlled by controlling the
15 thickness and the number of repetition deposition times of each matrix thin film 121 and semiconductor thin film 122 constituting the multilayer 120, the number of semiconductor quantum dots 132 embedded in the quantum dot nanowire 130 can be controlled by controlling the number of films of the
20 semiconductor thin film 122 constituting the multilayer 120, and the size of the semiconductor quantum dot 132 can be controlled by controlling the thickness of the semiconductor thin film 122 constituting the multilayer 120.

Also, the position of the semiconductor quantum dot 132

within the quantum dot nanowire 130 can be controller by controlling the position of the semiconductor thin film 122 within the multilayer 120.

Also, the major axis of the quantum dot nanowire
5 fabricated by etching the multilayer 120 is preferably controlled to have a length of several nanometers to several hundred nanometers by fabricating the multilayer 120 having the thickness of several nanometers to several hundred nanometers.

10 In order to fabricate the quantum dot nanowire having a contracted diameter of the order of several to several ten nanometers and the quantum dot nanowire array having a high density, the partial etching is preferably is a metal-assisted chemical etching using metal as catalysts or a reactive ion
15 etching (RIE).

FIG. 1 shows a fabricating method using the metal-assisted chemical etching. The multilayer 120 is fabricated by repeatedly depositing the matrix thin film 121 and the semiconductor thin film 122 so that the layer thickness
20 thereof becomes nanometer order, respectively, and then a catalyst metal which is Ag, Au or a transition metal, is deposited on an upper part of the multilayer 120 in a mesh type. The contracted diameter of the quantum dot nanowire 130 to be fabricated is determined according to the size of empty

cavity of the mesh-type catalyst metal 200. Preferably, the shape of catalyst metal is a mesh type where circular cavities having a diameter of the order of several to several ten nanometers are regularly arranged to be spaced from each other.

5 After the mesh type catalyst metal 200 performing catalysis on the etching is formed, the quantum dot nanowire 130 array whose one ends are contacted/fixed to the p-type semiconductor layer 110 and are regularly and densely arranged in a uniform size are fabricated.

10 Thereafter, an n-type semiconductor doped with opposite-type impurities is deposited on the p-type semiconductor layer 110.

At the time of the deposition, all empty spaces formed by the partial etching of the multilayer 120 on the upper part of
15 the p-type semiconductor layer are filled with an n-type semiconductor 140, and preferably, the quantum dot nanowire 130 array are completely covered therewith, to deposit them so that the n-type semiconductor 140 remains only on the surface.

This is to improve external extraction efficiency by
20 allowing electrons-holes generated from the semiconductor quantum dots 130 to be smoothly isolated and moved by absorbing light.

Thereafter, electrodes are formed on the lower part of the p-type semiconductor layer 110 and the surface of the n-

type semiconductor 140, respectively, thereby fabricating a solar cell according to the present invention.

FIG. 2 is a plan view showing a step of a mesh type catalyst metal and an etching step in the fabricating method of FIG. 1. After the mesh type catalyst metal 200 in which circular cavities having a diameter of order of several to several tens of nanometer are regularly arranged to be spaced from each other is formed on the upper part of a matrix layer 121 formed on the uppermost part of the multilayer 120, a wet chemical etching using the metal 200 as a catalyst is performed to fabricate quantum dot nanowire array having a regularly dense structure where they are arranged vertically to the p-type semiconductor layer 110.

FIG. 3 is a process cross-sectional view more precisely showing a step of fabricating quantum dot nanowire array by performing a chemical etching using a catalyst metal in the fabrication method according to the present invention. FIG. 3 shows a case where the semiconductor thin films 12 are deposited to have different thickness in order to fabricate quantum dot nanowires in which several sizes of semiconductor quantum dots are embeddingly arranged in a vertical direction of the nanowire.

In order to fabricate the quantum dot nanowire 130 at high density so that it has a high specific surface area and

to fabricate the contracted diameter of the quantum dot nanowire 130 in the order of several to several tens of nanometer, the mesh type catalyst metal 200 is preferably fabricated using nanoporous anodic aluminum oxide (AAO) 300 as
5 a mask.

The nanoporous anodic alumina oxide, which is anodic aluminum oxide formed with penetration porosities, can be fabricated by anodizing aluminum using sulfuric acid, oxalic acid or phosphoric acid as an electrolyte. The more detailed
10 fabrication method of the nanoporous anodic alumina oxide is disclosed in the present applicant's thesis (W. Lee et al. Nature Nanotech. 3, 402 (2008)) and reference therein.

More specifically, as shown in FIGS. 3 and 4, surface unevenness is formed on the surface of the multilayer 120 by
15 performing partial reactive ion etching (RIE) on the multilayer 120 using the nanoporous anodic alumina oxide 300 as a mask.

Therefore, the multilayer 120 is etched at a predetermined depth (etched of FIG. 4) in a shape of the
20 porosity portion (pore of FIG. 4) of the nanoporous anodic alumina oxide, thereby forming the surface unevenness.

Thereafter, the catalyst metal is deposited on the upper part of the multilayer 120' on which the surface unevenness is formed. At the time of the deposition, the catalyst metal is

selectively deposited on a convex region (region not etched by the RIE) by a surface step of the multilayer 120', thereby fabricating mesh type metals 200 in which cavities having similar size and arrangement with the nanoporous anodic alumina oxide are formed.

The metal 200 performing catalysis at the time of chemical etching is preferably Ag, Au or a catalyst metal which is a transition metal, wherein the transition metal is preferably Fe or Ni.

In the wet etching using the metal catalyst, etching solution is preferably a mixed aqueous solution mixed with hydrofluoric acid and aqueous hydrogen peroxide.

Preferably, the etching solution is a mixed solution having the volume ratio of hydrofluoric acid: aqueous hydrogen peroxide: water being 1: 0.3~0.7: 3~4. This is the substances and ratio that can efficiently etch the semiconductor thin film 122 and the matrix thin film 121 constituting the multilayer 120 under the metal catalyst, and the condition for fabricating the quantum dot nanowire 130 having the even surface irrespective of the length thereof.

As the wet etching is processed, the quantum dot nanowire shape in which nano disc shaped matrix and nanodisc-shaped semiconductor are repeatedly coupled in sequence is fabricated, wherein the surface of the nanodisc shaped semiconductor

reacts to oxygen (aqueous hydrogen peroxide, water) contained in the etching solution so that the surface thereof is naturally oxidized. Thereby, the surface of the semiconductor which was in a nanodisc shape is naturally oxidized by the etching liquid, consequently having a structure that the semiconductor is embedded inside the quantum dot nanowire in a quantum dot shape.

Through the chemical etching using the metal mesh 200 and the metal catalyst using the nanoporous anodic alumina oxide (AAO), the contracted diameter of the quantum dot nanowire can be fabricated having a very fine nanowire of 5nm to 25nm at high density of about 2×10^{10} to $3 \times 10^{10}/\text{cm}^2$ (see the present applicant's thesis Nano Lett. 8, 3046-3051, 2008).

FIG. 5 is a process cross-sectional view showing a step of fabricating a quantum dot nanowire array by performing a reactive ion etching in the fabrication method according to the present invention.

After a multilayer 120 is formed through a deposition process, the quantum dot nanowire array can be fabricated by using the chemical wet etching using the aforementioned metal catalyst, and the quantum dot nanowire array can be fabricated by using the nanoporous anodic aluminum oxide (AAO) and the reactive ion etching (RIE) as shown in FIG. 5.

As shown in FIG. 5, metal is deposited on the upper part

of the multilayer 120 using the nanoporous anodic aluminum oxide (AAO) 300 as a mask. At this time, the metal is deposited on the upper part of the multilayer 120 having the size and arrangement similar to those of the porosities of the nanoporous anodic alumina oxide. The quantum dot nanowire 130 array is fabricated by performing a reactive ion etching (RIE) vertically on the p-type semiconductor layer 110, using a circular metal dot (circular disc shaped metal in a nano size) 210 fabricated through the metal deposition process as a mask.

At this time, when being exposed to air after the reactive ion etching is performed, the surface of the semiconductor is naturally oxidized by oxygen, thereby having a semiconductor quantum dot shape where the semiconductor is embedded inside the quantum dot nanowire 130 in the same manner as the chemical wet etching.

The method shown in FIG. 5 can fabricate fine nanowires having the thickness of several nanometers at high density, in spite of somewhat long process time compared to the chemical wet etching. In the RIE process, SF_6/O_2 plasma (40 sccm, 10 mTorr and 200W) is preferably used and an advantage is obtained in that the length of the quantum dot nanowire can be controlled by adjusting the time of RIE.

The following can be obtained through the fabrication method according to the present invention described with

reference to FIGS. 1 to 5.

After the matrix layer and semiconductor layer having the thickness of several nanometers are deposited sequentially on the upper part of the p-type semiconductor or the n-type semiconductor of p-n junctions of the optical device, fine
5 quantum dot nanowire array having density is fabricated in a top-down method through a chemical wet etching using the nanoporous anodic alumina oxide or the catalyst metal; or a dry etching using the nanoporous anodic alumina oxide or the
10 reactive ion etching.

The surface of the semiconductor constituting the quantum dot nanowire is naturally oxidized by being subject to etching agent during the etching or oxygen atmosphere after the etching is completed, thereby forming a structure that is
15 embedded inside the quantum dot nanowire in a semiconductor quantum dot shape.

The empty space between quantum dot nanowires generated by being etched is deposited with the semiconductor substances doped with opposite-type impurities to form the p-n junction
20 having a high movement efficiency of electrons/holes.

The thickness of the semiconductor thin film and the sort of substances of matrix thin film are controlled during the deposition process of the multilayer to finally control the band gap energy of the semiconductor quantum dot inside the

quantum dot nanowire.

The semiconductor thin films having different thickness are deposited alternately with the matrix thin film during the deposition process of the multilayer to have various ranges of
5 band gap energy, making it possible to absorb light in a wide wavelength region from infrared rays to visible rays.

The multilayer may be deposited through a general semiconductor deposition process using a PVD or a CVD. The deposition of the semiconductor materials doped with the
10 opposite-type impurities may be performed through a general semiconductor process using a PVD or a CVD, preferably, the deposition using the CVD.

The electrodes 151 and 152 are fabricated using a general printing method such as a screen printing using conductive
15 metal paste and a stencil printing or a deposition method using a PVD/CVD.

The fabrication method according to the present invention can easily control the light absorption wavelength (band gap of semiconductor quantum dot) by means of the sort of matrix,
20 the size of semiconductor quantum dot constituting the quantum dot nanowire or the combination thereof, and further can easily and rapidly fabricate a low dimensional nanostructure shaped photoactive layer in a top-down method with a low cost.

The fabrication method according to the present invention

can fabricate the solar cell using semiconductive substances generating a pair of electron-hole absorbing light as the semiconductor quantum dot, semiconductive substances doped with p-type impurities as the p-type semiconductor, 5 semiconductive substances doped with n-type impurities as the n-type semiconductor, and nitride or oxide of the semiconductive substances as the matrix. However, in order to efficiently fabricate the solar cell using the present invention, preferably, the semiconductor substrate is a p-type 10 silicon substrate, the semiconductor doped with the opposite-type impurities is a n-type silicon, the matrix is silicon oxide or silicon nitride, and the semiconductor of the multilayer is silicon.

FIG. 6 shows a cross-section structure of a solar cell 15 fabricated according to the fabrication method of the present invention. Referring to FIG. 6, the solar cell includes a lower electrode 152; a first semiconductor layer formed on the lower electrode and doped with n-type or p-type impurities; a second semiconductor layer 140 formed over the first 20 semiconductor layer and doped with impurities opposite-type to the first semiconductor layer 110; an upper electrode 151 formed on the semiconductor layer 140; and quantum dot nanowire 130 array vertically arranged in the second semiconductor layer 140 to be spaced from each other, wherein

the quantum dot nanowires 130, whose one ends contact the first semiconductor layer 110, include matrix 131 and at least one semiconductor quantum dots 132 surrounded by the matrix.

At this time, the other ends of the quantum dot nanowires
5 130 are present on the surface of the second semiconductor layer 140 so that the other ends may contact the upper electrode 151 or the other ends of the quantum dot nanowires 130 are present in the second semiconductor layer 140 so that the quantum dot nanowires 130 may be embedded in the second
10 semiconductor layer 140.

The matrix 131 is semiconductor nitride, semiconductor oxide or a mixture thereof.

Preferably, the first semiconductor layer 110 and the second semiconductor layer 140 have the same semiconductive
15 substances doped with impurities opposite-type to each other, and the matrix is nitride of semiconductive substances of the first or second semiconductor layers 110 and 140, oxide of semiconductive substances of the first or second semiconductor layers 110 and 140, or a mixture thereof

20 In the quantum dot nanowire 130, two or more semiconductor quantum dots 132 are arranged vertically to the quantum dot nanowire 130, wherein the semiconductor quantum dots 132 provided in the quantum dot nanowire 130 have different sizes. At this time, the diameter of the

semiconductor quantum dot provided in the quantum dot nanowire is 1 nm to 10nm, the contracted diameter of the quantum dot nanowire is 5nm to 10nm, and the density of the quantum dot nanowire is 2×10^{10} to $3 \times 10^{10}/\text{cm}^2$.

5 With the solar cell according to the present invention, the size of the semiconductor quantum dot and the sort of matrix are controlled, making it possible to easily control the band gap energy of the semiconductor quantum dot, the semiconductor quantum dots having different sizes are provided
10 in the quantum dot nanowire, making it possible to perform the photoelectric conversion in the wide spectrum from visible rays to infrared rays, the photoactive part where a photoelectric conversion occurs is in a low dimensional nanostructure shape of high density quantum dot nanowire array,
15 making it possible to maximize light absorption, the quantum dot nanowire contact p-type and n-type semiconductor over a wide area, making it possible to improve conduction efficiency of electrons and holes.

More specifically, the solar cell according to the
20 present invention performs a photoelectric conversion on all wavelength regions of the solar cell by controlling the band gap energy of the silicon quantum dot to maximize the internal light generating efficiency, constitutes the photoactive part in a low dimensional nanostructure shape having a high

specific surface area to maximize the light absorption and photoelectric conversion efficiency, and has quantum dot nanowires each having a structure being surrounded by the n-type semiconductor and contacting the p-type semiconductor to
5 improve conduction efficiency of electrons-holes generated by the light.

Preferably, the first semiconductor layer is a p-type silicon layer, the n-type semiconductor layer is an n-type silicon layer, the matrix is silicon oxide, silicon nitride or
10 a mixture thereof, and the semiconductor quantum dot is a silicon quantum dot.

Those skilled in the art will appreciate that the conceptions and specific embodiments disclosed in the foregoing description may be readily utilized as a basis for
15 modifying or designing other embodiments for carrying out the same purposes of the present invention. Those skilled in the art will also appreciate that such equivalent embodiments do not depart from the spirit and scope of the invention as set forth in the appended claims.

【CLAIMS】

【Claim 1】

A fabrication method of a solar cell having quantum dot nanowire array comprising:

5 a) fabricating a multilayer by repeatedly stacking matrix layers formed of semiconductor nitride or semiconductor oxide, and semiconductor layers on an upper part of a semiconductor substrate doped with p-type or n-type impurities;

10 b) fabricating a quantum dot nanowire array constituted by a plurality of quantum dot nanowires whose one ends are fixed on the semiconductor substrate and are spaced from each other to be vertically arranged by partially etching the multilayer vertically to the semiconductor substrate and;

15 c) depositing a semiconductor doped with the opposite-type impurities to impurities of the semiconductor substrate on the upper part of the semiconductor substrate formed with the quantum dot nanowire array and filling at least empty spaces between the other ends of the quantum dot nanowires and the semiconductor substrate with the semiconductor doped with
20 opposite-type impurities; and

 d) forming a lower electrode on a lower part of the semiconductor substrate, and forming an upper electrode on an upper part surface formed with the quantum dot nanowire array and semiconductor surface doped with the opposite-type

impurities or on an upper part of semiconductor surface doped with the opposite-type impurities so that the upper electrode corresponds to the lower electrode.

5 **【Claim 2】**

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the multilayer of a) step is fabricated through a deposition process using PVD or CVD, and the thickness of the semiconductor layers constituting the multilayer are different.

【Claim 3】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1 or 2, wherein the semiconductor layer and the matrix layer constituting the multilayer have the thickness of less than 10nm, independently from each other.

【Claim 4】

20 The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the step b) further comprises:

b1-1) depositing Ag, Au or a catalyst metal that is a transition metal on the upper part of the multilayer in a mesh

type; and b1-2) performing a wet etching using mixed aqueous solution containing hydrofluoric acid and hydrogen peroxide.

【Claim 5】

5 The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the step b) further comprises:

 b2-1) forming circular metal nano dot array on the upper part of the multilayer; and

10 b2-2) performing a reactive ion etching (RIE) using the metal nano dots as masks.

【Claim 6】

 The fabrication method of the solar cell having quantum
15 dot nanowire array according to claim 4 or 5, wherein quantum dot nanowires whose semiconductor quantum dots are embedded in the matrix are fabricated by the etching of the step b), and the size of the semiconductor quantum dots is controlled by the thickness of each semiconductor layers constituting the
20 multilayer.

【Claim 7】

 The fabrication method of the solar cell having quantum dot nanowire array according to claim 6, wherein a light

absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot constituting the quantum dot nanowire or the combination thereof.

5

【Claim 8】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 3, wherein the step c) is the deposition using a CVD or a PVD.

10

【Claim 9】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, 2, 4, 5 or 7, wherein the semiconductor substrate is a p-type or an n-type silicon substrate, the semiconductor doped with the opposite-type impurities is an n-type or a p-type silicon, the matrix is silicon oxide or silicon nitride, and the semiconductor layers of the multilayer is silicon layers.

15

20 **【Claim 10】**

A solar cell having quantum dot nanowire array fabricated using a fabrication method according to any one of claim 1, 2, 4, 5, 7 or 8, comprising:

a lower electrode;

a first semiconductor layer formed on an upper part of the lower electrode and doped with n-type or p-type impurities;

a second semiconductor layer formed over the first
5 semiconductor layer and doped with impurities opposite -type to the first semiconductor layer;

an upper electrode formed on an upper part of the semiconductor layer; and

a quantum dot nanowire array constituted by a plurality
10 of quantum dot nanowires vertically arranged in the second semiconductor layer to be spaced from each other,
wherein the quantum dot nanowire that constitutes the quantum dot nanowire array, whose one end contacts the first semiconductor layer, includes matrix and at least one
15 semiconductor quantum dots surrounded by the matrix.

【Claim 11】

The solar cell having quantum dot nanowire array according to claim 10, wherein the matrix is semiconductor
20 nitride, semiconductor oxide or a mixture thereof.

【Claim 12】

The solar cell having quantum dot nanowire array according to claim 10, wherein the quantum dot nanowire that

constitutes the quantum dot nanowire array has two or more semiconductor quantum dots arranged vertically to the quantum dot nanowires.

5 **【Claim 13】**

The solar cell having quantum dot nanowire array according to claim 12, wherein the quantum dot nanowire is configured of the semiconductor quantum dots having different sizes.

10

【Claim 14】

The solar cell having quantum dot nanowire array according to claim 10, 12 or 13, wherein the diameter of the semiconductor quantum dot in the quantum dot nanowire is less
15 than 10nm.

【Claim 15】

The solar cell having quantum dot nanowire array according to any one of claims 10, 11, 12, or 13, wherein a
20 light absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot or the combination thereof.

【Claim 16】

The solar cell having quantum dot nanowire array according to claim 15, wherein the first semiconductor layer is a p-type silicon layer, the second semiconductor layer is an n-type silicon layer, the matrix is silicon oxide, silicon
5 nitride or a mixture thereof, and the semiconductor quantum dot is a silicon quantum dot.

AMENDED CLAIMS
received at the International Bureau on 20 July 2009 (20.07.2009)
+ STATEMENT

【Claim 1】 (No changes)

【Claim 2】 (No changes)

5

【Claim 3】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the semiconductor layer and the matrix layer constituting the multilayer have the thickness of less than 10nm, independently from each other.

【Claim 4】 (No changes)

15 【Claim 5】 (No changes)

【Claim 6】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein quantum dot nanowires whose semiconductor quantum dots are embedded in the matrix are fabricated by the etching of the step b), and the size of the semiconductor quantum dots is controlled by the thickness of each semiconductor layers constituting the multilayer.

25

【Claim 7】 (No changes)

【Claim 8】 (No changes)

5 【Claim 9】

 The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the semiconductor substrate is a p-type or an n-type silicon substrate, the semiconductor doped with the opposite-type impurities is an n-type or a p-type silicon, the matrix is silicon oxide or silicon nitride, and the semiconductor layers of the multilayer is silicon layers.

 【Claim 10】

15 A solar cell having quantum dot nanowire array fabricated using a fabrication method according to claim 1 comprising:

 a lower electrode;

 a first semiconductor layer formed on an upper part of the lower electrode and doped with n-type or p-type impurities;

20 a second semiconductor layer formed over the first semiconductor layer and doped with impurities opposite -type to the first semiconductor layer;

 an upper electrode formed on an upper part of the semiconductor layer; and

a quantum dot nanowire array constituted by a plurality of quantum dot nanowires vertically arranged in the second semiconductor layer to be spaced from each other, wherein the quantum dot nanowire that constitutes the quantum dot nanowire array, whose one end contacts the first semiconductor layer, includes matrix and at least one semiconductor quantum dots surrounded by the matrix.

【Claim 11】 (No changes)

【Claim 12】 (No changes)

【Claim 13】 (No changes)

【Claim 14】

The solar cell having quantum dot nanowire array according to claim 10, wherein the diameter of the semiconductor quantum dot in the quantum dot nanowire is less than 10nm.

【Claim 15】

The solar cell having quantum dot nanowire array according to claim 10, wherein a light absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot or the combination thereof.

【Claim 16】 (No changes)

STATEMENT UNDER ARTICLE 19(1)

The originally filed specification of the present application amended as the claim 3,6,9,10,14 and 15.

5

Original Claims

【Claim 1】

A fabrication method of a solar cell having quantum dot nanowire array comprising:

10 a) fabricating a multilayer by repeatedly stacking matrix layers formed of semiconductor nitride or semiconductor oxide, and semiconductor layers on an upper part of a semiconductor substrate doped with p-type or n-type impurities;

15 b) fabricating a quantum dot nanowire array constituted by a plurality of quantum dot nanowires whose one ends are fixed on the semiconductor substrate and are spaced from each other to be vertically arranged by partially etching the multilayer vertically to the semiconductor substrate and;

20 c) depositing a semiconductor doped with the opposite-type impurities to impurities of the semiconductor substrate on the upper part of the semiconductor substrate formed with the quantum dot nanowire array and filling at least empty spaces between the other ends of the quantum dot nanowires and the semiconductor substrate with the semiconductor doped with
25 opposite-type impurities; and

d) forming a lower electrode on a lower part of the semiconductor substrate, and forming an upper electrode on an upper part surface formed with the quantum dot nanowire array and semiconductor surface doped with the opposite-type impurities or on an upper part of semiconductor surface doped with the opposite-type impurities so that the upper electrode corresponds to the lower electrode.

【Claim 2】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the multilayer of a) step is fabricated through a deposition process using PVD or CVD, and the thickness of the semiconductor layers constituting the multilayer are different.

【Claim 3】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1 or 2, wherein the semiconductor layer and the matrix layer constituting the multilayer have the thickness of less than 10nm, independently from each other.

【Claim 4】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the step b)

further comprises:

b1-1) depositing Ag, Au or a catalyst metal that is a transition metal on the upper part of the multilayer in a mesh type; and b1-2) performing a wet etching using mixed aqueous
5 solution containing hydrofluoric acid and hydrogen peroxide.

【Claim 5】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the step b)
10 further comprises:

b2-1) forming circular metal nano dot array on the upper part of the multilayer; and
b2-2) performing a reactive ion etching (RIE) using the metal nano dots as masks.

15

【Claim 6】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 4 or 5, wherein quantum dot nanowires whose semiconductor quantum dots are embedded in
20 the matrix are fabricated by the etching of the step b), and the size of the semiconductor quantum dots is controlled by the thickness of each semiconductor layers constituting the multilayer.

25 **【Claim 7】**

The fabrication method of the solar cell having quantum dot nanowire array according to claim 6, wherein a light absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot constituting the quantum dot nanowire or the combination thereof.

【Claim 8】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 3, wherein the step c) is the deposition using a CVD or a PVD.

【Claim 9】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, 2, 4, 5 or 7, wherein the semiconductor substrate is a p-type or an n-type silicon substrate, the semiconductor doped with the opposite-type impurities is an n-type or a p-type silicon, the matrix is silicon oxide or silicon nitride, and the semiconductor layers of the multilayer is silicon layers.

【Claim 10】

A solar cell having quantum dot nanowire array fabricated using a fabrication method according to any one of claim 1, 2, 4, 5, 7 or 8, comprising:

a lower electrode;

a first semiconductor layer formed on an upper part of the lower electrode and doped with n-type or p-type impurities;

5 a second semiconductor layer formed over the first semiconductor layer and doped with impurities opposite -type to the first semiconductor layer;

an upper electrode formed on an upper part of the semiconductor layer; and

10 a quantum dot nanowire array constituted by a plurality of quantum dot nanowires vertically arranged in the second semiconductor layer to be spaced from each other, wherein the quantum dot nanowire that constitutes the quantum dot nanowire array, whose one end contacts the first
15 semiconductor layer, includes matrix and at least one semiconductor quantum dots surrounded by the matrix.

【Claim 11】

The solar cell having quantum dot nanowire array
20 according to claim 10, wherein the matrix is semiconductor nitride, semiconductor oxide or a mixture thereof.

【Claim 12】

The solar cell having quantum dot nanowire array
25 according to claim 10, wherein the quantum dot nanowire that

constitutes the quantum dot nanowire array has two or more semiconductor quantum dots arranged vertically to the quantum dot nanowires.

5 **【Claim 13】**

The solar cell having quantum dot nanowire array according to claim 12, wherein the quantum dot nanowire is configured of the semiconductor quantum dots having different sizes.

10

【Claim 14】

The solar cell having quantum dot nanowire array according to claim 10, 12 or 13, wherein the diameter of the semiconductor quantum dot in the quantum dot nanowire is less than 10nm.

15

【Claim 15】

The solar cell having quantum dot nanowire array according to any one of claims 10, 11, 12, or 13, wherein a light absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot or the combination thereof.

20

【Claim 16】

The solar cell having quantum dot nanowire array

25

according to claim 15, wherein the first semiconductor layer is a p-type silicon layer, the second semiconductor layer is an n-type silicon layer, the matrix is silicon oxide, silicon nitride or a mixture thereof, and the semiconductor quantum
5 dot is a silicon quantum dot.

Amended Claims

【Claim 1】

A fabrication method of a solar cell having quantum dot
10 nanowire array comprising:

a) fabricating a multilayer by repeatedly stacking matrix layers formed of semiconductor nitride or semiconductor oxide, and semiconductor layers on an upper part of a semiconductor substrate doped with p-type or n-type impurities;

15 b) fabricating a quantum dot nanowire array constituted by a plurality of quantum dot nanowires whose one ends are fixed on the semiconductor substrate and are spaced from each other to be vertically arranged by partially etching the multilayer vertically to the semiconductor substrate and;

20 c) depositing a semiconductor doped with the opposite-type impurities to impurities of the semiconductor substrate on the upper part of the semiconductor substrate formed with the quantum dot nanowire array and filling at least empty spaces between the other ends of the quantum dot nanowires and
25 the semiconductor substrate with the semiconductor doped with

opposite-type impurities; and

d) forming a lower electrode on a lower part of the semiconductor substrate, and forming an upper electrode on an upper part surface formed with the quantum dot nanowire array and semiconductor surface doped with the opposite-type impurities or on an upper part of semiconductor surface doped with the opposite-type impurities so that the upper electrode corresponds to the lower electrode.

10 **【Claim 2】**

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the multilayer of a) step is fabricated through a deposition process using PVD or CVD, and the thickness of the semiconductor layers constituting the multilayer are different.

【Claim 3】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the semiconductor layer and the matrix layer constituting the multilayer have the thickness of less than 10nm, independently from each other.

【Claim 4】

25 The fabrication method of the solar cell having quantum

dot nanowire array according to claim 1, wherein the step b) further comprises:

b1-1) depositing Ag, Au or a catalyst metal that is a transition metal on the upper part of the multilayer in a mesh type; and b1-2) performing a wet etching using mixed aqueous solution containing hydrofluoric acid and hydrogen peroxide.

【Claim 5】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the step b) further comprises:

b2-1) forming circular metal nano dot array on the upper part of the multilayer; and

b2-2) performing a reactive ion etching (RIE) using the metal nano dots as masks.

【Claim 6】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein quantum dot nanowires whose semiconductor quantum dots are embedded in the matrix are fabricated by the etching of the step b), and the size of the semiconductor quantum dots is controlled by the thickness of each semiconductor layers constituting the multilayer.

【Claim 7】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 6, wherein a light absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot constituting the quantum dot nanowire or the combination thereof.

【Claim 8】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 3, wherein the step c) is the deposition using a CVD or a PVD.

【Claim 9】

The fabrication method of the solar cell having quantum dot nanowire array according to claim 1, wherein the semiconductor substrate is a p-type or an n-type silicon substrate, the semiconductor doped with the opposite-type impurities is an n-type or a p-type silicon, the matrix is silicon oxide or silicon nitride, and the semiconductor layers of the multilayer is silicon layers.

【Claim 10】

A solar cell having quantum dot nanowire array fabricated using a fabrication method according to claim 1 comprising:

a lower electrode;

a first semiconductor layer formed on an upper part of the lower electrode and doped with n-type or p-type impurities;

5 a second semiconductor layer formed over the first semiconductor layer and doped with impurities opposite -type to the first semiconductor layer;

an upper electrode formed on an upper part of the semiconductor layer; and

10 a quantum dot nanowire array constituted by a plurality of quantum dot nanowires vertically arranged in the second semiconductor layer to be spaced from each other, wherein the quantum dot nanowire that constitutes the quantum dot nanowire array, whose one end contacts the first
15 semiconductor layer, includes matrix and at least one semiconductor quantum dots surrounded by the matrix.

【Claim 11】

The solar cell having quantum dot nanowire array
20 according to claim 10, wherein the matrix is semiconductor nitride, semiconductor oxide or a mixture thereof.

【Claim 12】

The solar cell having quantum dot nanowire array
25 according to claim 10, wherein the quantum dot nanowire that

constitutes the quantum dot nanowire array has two or more semiconductor quantum dots arranged vertically to the quantum dot nanowires.

5 **【Claim 13】**

The solar cell having quantum dot nanowire array according to claim 12, wherein the quantum dot nanowire is configured of the semiconductor quantum dots having different sizes.

10

【Claim 14】

The solar cell having quantum dot nanowire array according to claim 10, wherein the diameter of the semiconductor quantum dot in the quantum dot nanowire is less

15 than 10nm.

【Claim 15】

The solar cell having quantum dot nanowire array according to claim 10, wherein a light absorption wavelength is controlled by means of the sort of the matrix, the size of the semiconductor quantum dot or the combination thereof.

20

【Claim 16】

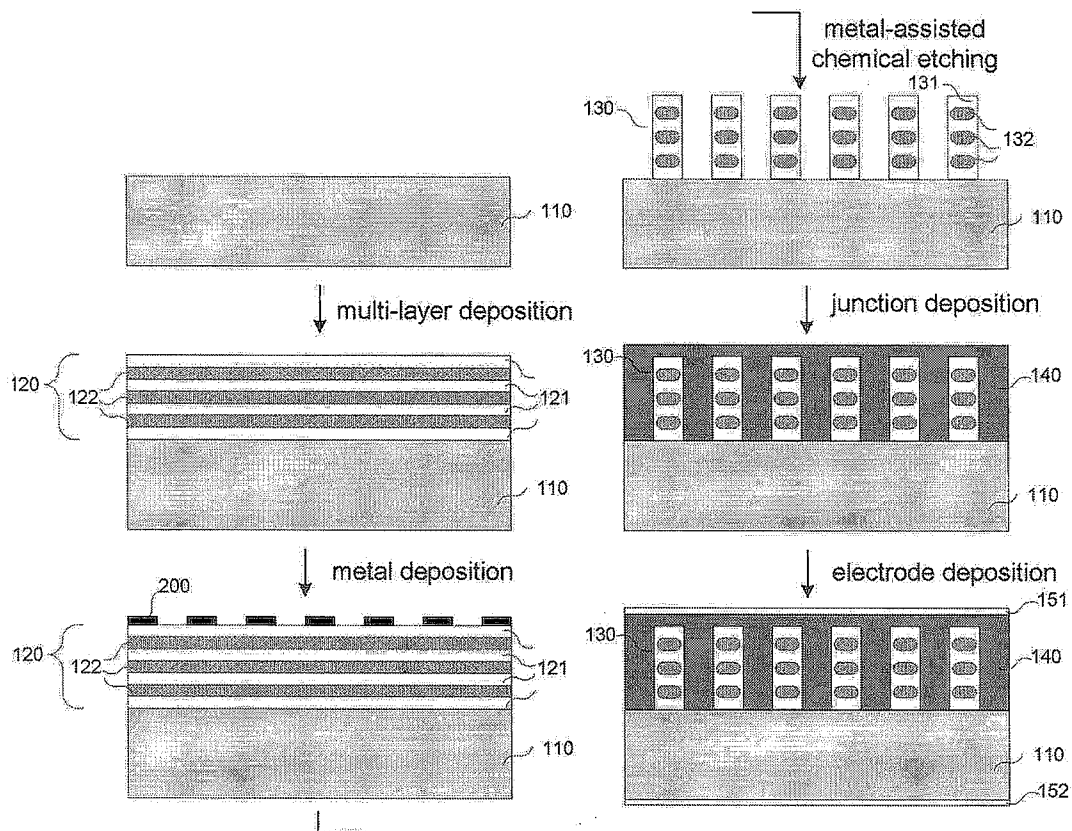
The solar cell having quantum dot nanowire array according to claim 15, wherein the first semiconductor layer

25

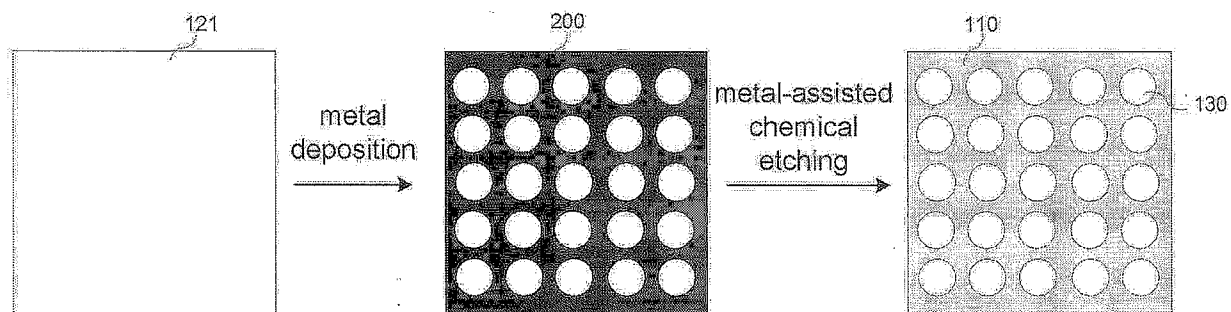
is a p-type silicon layer, the second semiconductor layer is an n-type silicon layer, the matrix is silicon oxide, silicon nitride or a mixture thereof, and the semiconductor quantum dot is a silicon quantum dot.

【DRAWINGS】

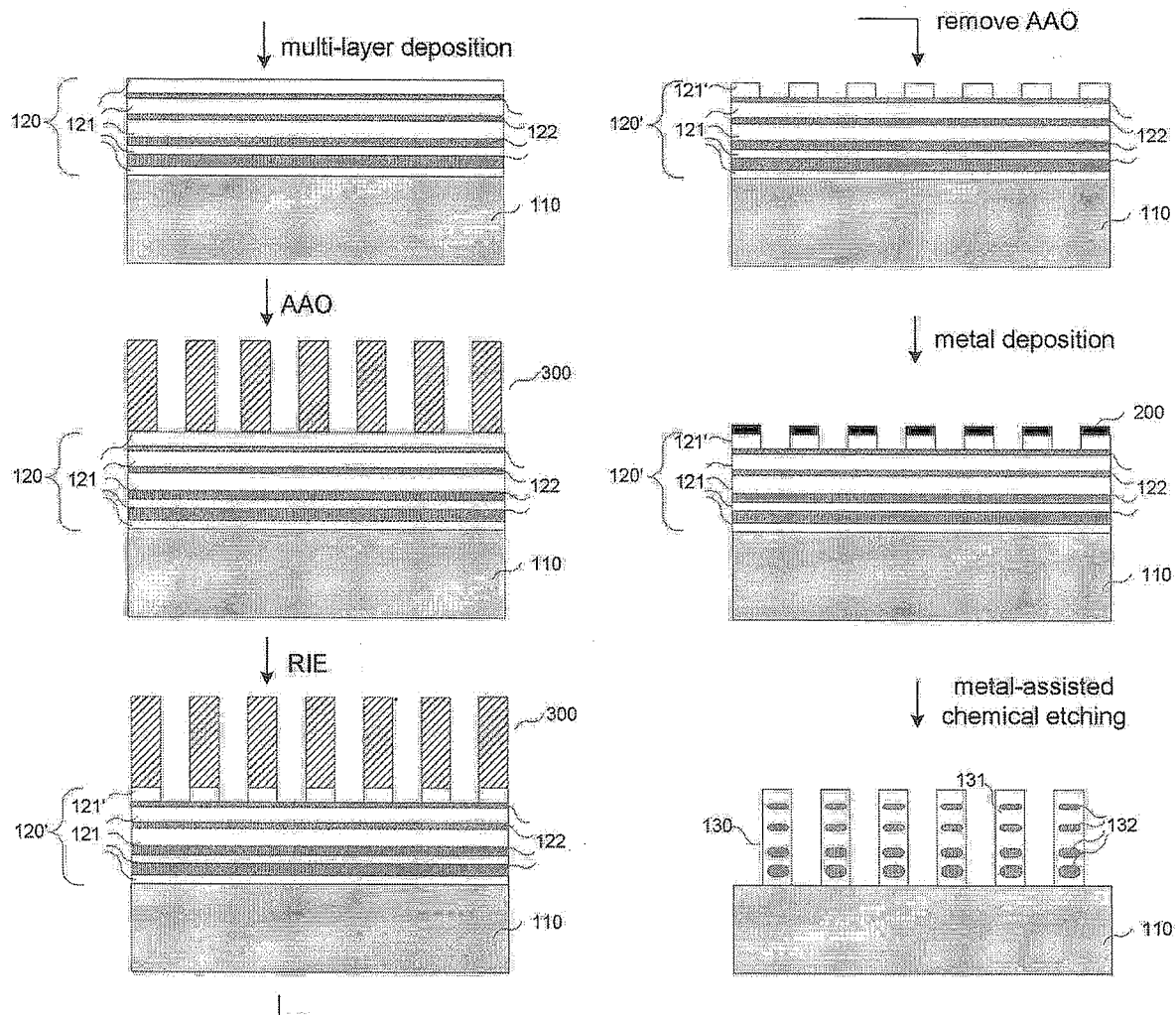
【Figure 1】



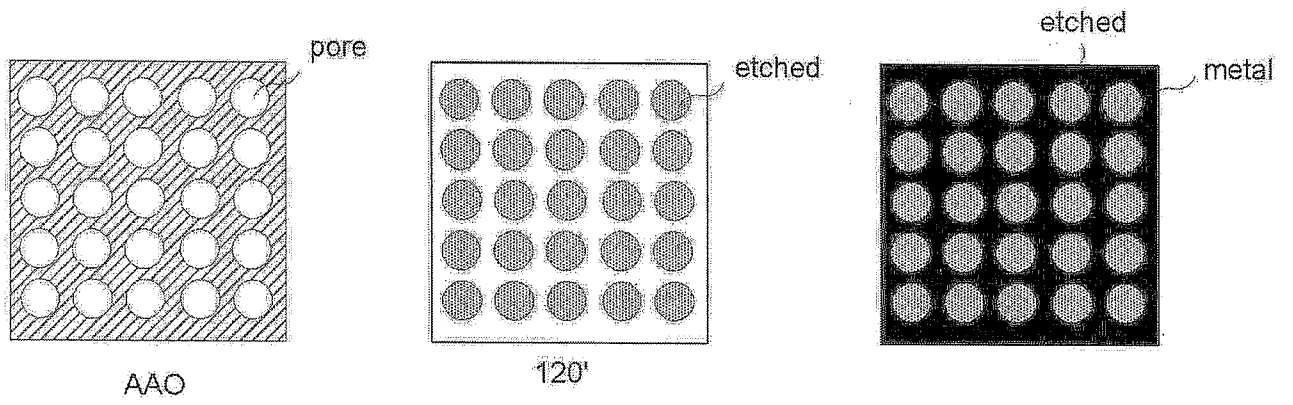
【Figure 2】



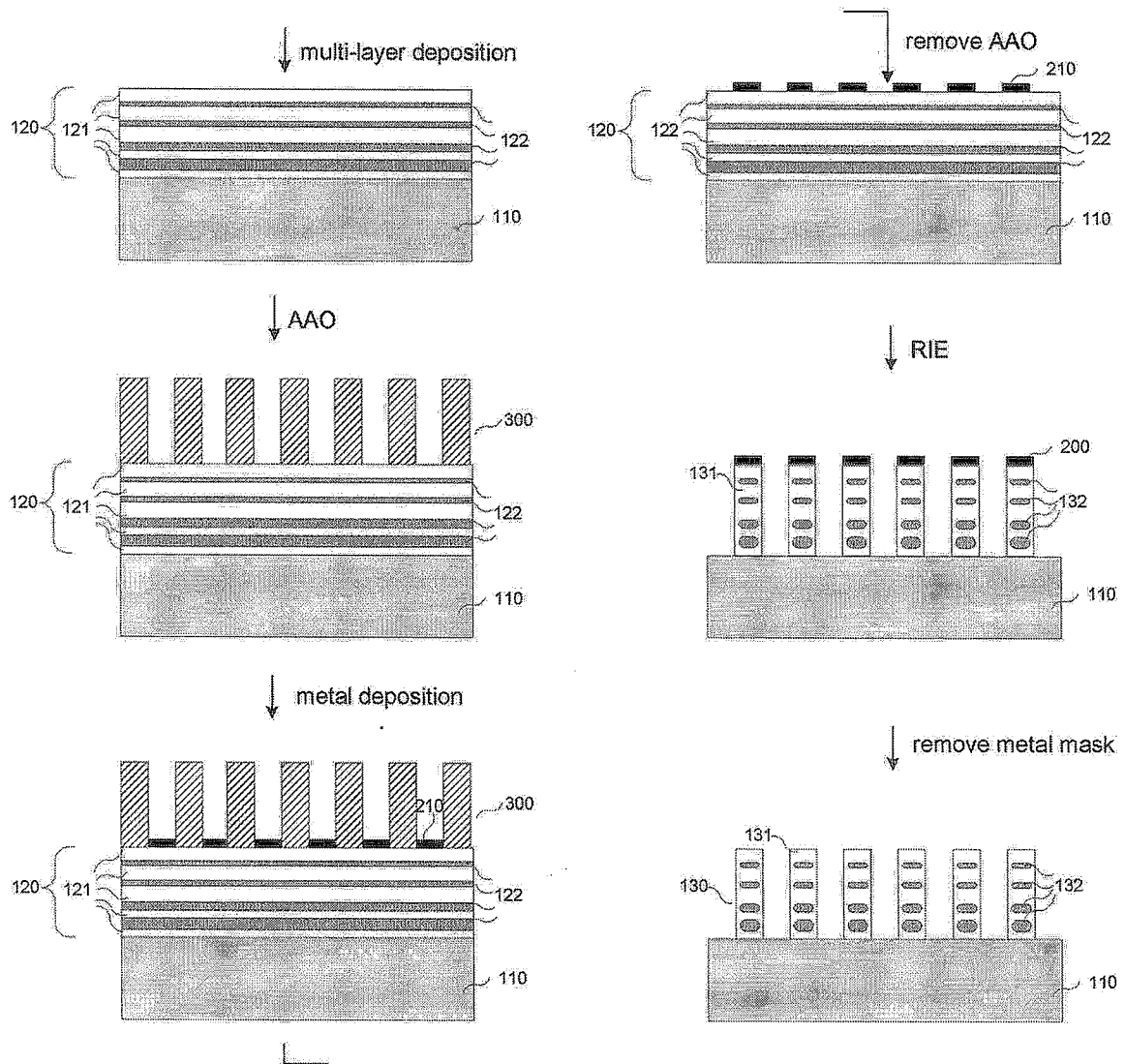
【Figure 3】



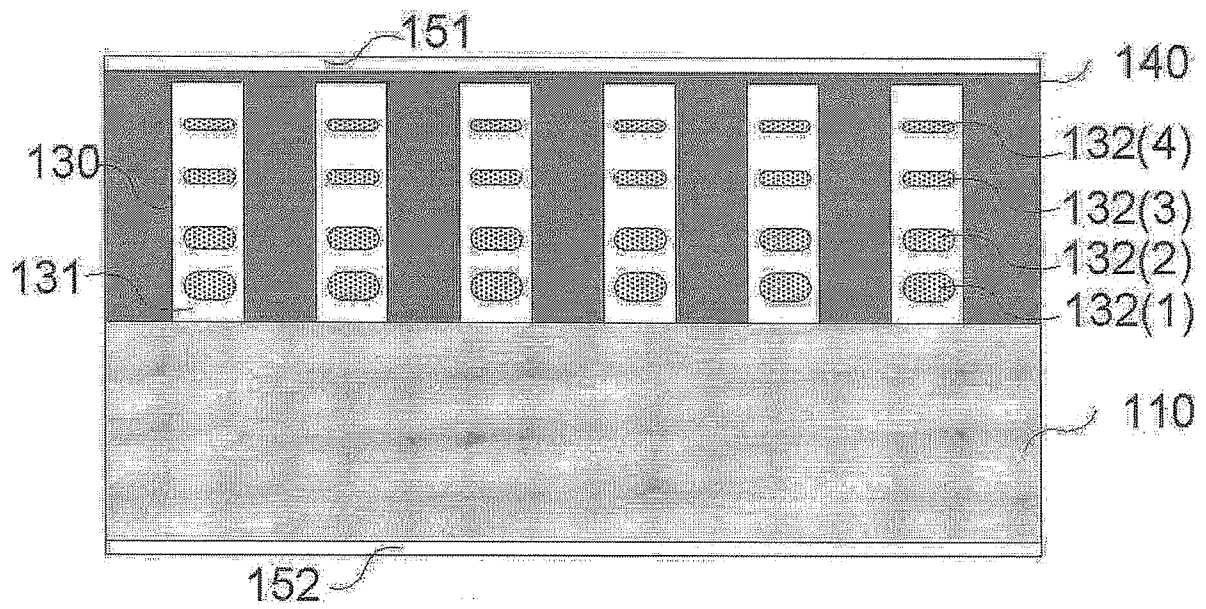
【Figure 4】



【Figure 5】



【Figure 6】



A. CLASSIFICATION OF SUBJECT MATTER***H01L 31/042(2006.01)i***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC8 H01L31/042

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and Applications for Utility models since 1975

Japanese Utility models and Applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS(KIPO Internal)

"Keywords: quantum, dot, solar, photovoltaic"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 2007-098378 A1 (SOLEXANT CORP.) 30 August 2007 See the whole document	1, 10 2-9, 11-16
A	US 2008/0178924 A1 (KRZYSZTO KEMPA et al.) 31 July 2008 See the Abstract, Figure 2	1-16
A	US 2008/0011349 A1 (RYNE P. RAFFAELE et al.) 17 January 2008 See the Abstract	1-16
A	WO 2005-069387 A1 (CYRIUM TECHNOLOGIES INCORPORATED et al.) 28 July 2005 See the Abstract	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

27 MAY 2009 (27.05.2009)

Date of mailing of the international search report

27 MAY 2009 (27.05.2009)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
Government Complex-Daejeon, 139 Seonsa-ro, Seo-
gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

MUN, Tae Jin

Telephone No. 82-42-481-8479



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2008/006618

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007-098378 A1	30.08.2007	AU 2007-217091 A1 EP 1989744 A1 KR 10-2008-0097462 A TW 200802903 A	30.08.2007 12.11.2008 05.11.2008 01.01.2008
US 2008/0178924 A1	31.07.2008	None	
US 2008/0011349 A1	17.01.2008	None	
WO 2005-069387 A1	28.07.2005	AU 2005-205373 A1 PI 0506541 A CA 2551123 A1 CN 1910759 A EP 1709690 A1 JP 2007-519237 A	28.07.2005 27.02.2007 28.07.2005 07.02.2007 11.10.2006 12.07.2007