



(51) International Patent Classification:
H01L 31/042 (2006.01)

(21) International Application Number:
PCT/KR2010/009041

(22) International Filing Date:
17 December 2010 (17.12.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10-2010-0026216 24 March 2010 (24.03.2010) KR

(71) Applicant (for all designated States except US):
GWANGJU INSTITUTE OF SCIENCE AND TECHNOLOGY [KR/KR]; 1 Oryong-dong, Buk-gu, Gwangju 500-712 (KR).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **JEONG, Yon Kil** [KR/KR]; Solar Energy Research Institute, GIST, 1 Oryong-dong, Buk-gu, Gwangju 500-712 (KR). **MOON, Seung-Hyeon** [KR/KR]; Solar Energy Research Institute, GIST, 1 Oryong-dong, Buk-gu, Gwangju 500-712 (KR). **PARK, Dong-Won** [KR/KR]; Solar Energy Research Institute, GIST, 1 Oryong-dong, Buk-gu, Gwangju 500-712 (KR). **SHIM, Hee-Sang** [KR/KR]; Solar Energy Research Institute, GIST, 1 Oryong-dong, Buk-gu, Gwangju 500-712 (KR). **OH, Seung-Hwan** [KR/KR]; Solar Energy Research Institute, GIST, 1 Oryong-dong, Buk-gu, Gwangju 500-712 (KR). **LEE, Jae-Kwang** [KR/KR]; So-

lar Energy Research Institute, GIST, 1 Oryong-dong, Buk-gu, Gwangju 500-712 (KR).

(74) Agent: **E-SANG PATENT & TRADEMARK LAW FIRM**; 3F., Woodo Bldg., 82-2, Yangjae-dong, Seocho-gu, Seoul 137-890 (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, CL, 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, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

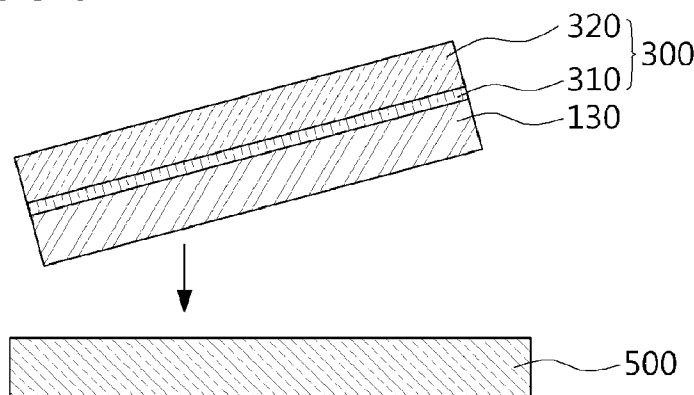
Published:

— with international search report (Art. 21(3))

[Continued on next page]

(54) Title: METHOD FOR FABRICATING METAMORPHIC COMPOUND SEMICONDUCTOR SOLAR CELL

[Fig. 4]



(57) Abstract: A method of fabricating a metamorphic compound semiconductor solar cell is provided. The method includes forming a graded buffer layer on a support substrate, the graded buffer layer having a graded lattice constant from a bottom surface thereof toward a top surface thereof. A sacrificial layer is formed on the graded buffer layer. A solar cell structure is formed on the sacrificial layer. A support structure is formed on the solar cell structure. The sacrificial layer is selectively etched to separate the solar cell structure from the graded buffer layer. The separated solar cell structure is bonded to a host substrate.





-
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

Description

Title of Invention: METHOD FOR FABRICATING METAMORPHIC COMPOUND SEMICONDUCTOR SOLAR CELL

Technical Field

- [1] The present invention relates to a method of fabricating a metamorphic compound semiconductor solar cell, and more particularly, to a method of fabricating a metamorphic compound semiconductor solar cell using a lattice-mismatched growth technique.

Background Art

- [2] In general, a solar cell using a compound semiconductor, particularly, a Group III-V compound semiconductor, which has a direct transition bandgap, exhibits a higher light absorbance and is more capable of absorbing solar energy incident on the solar cell than a silicon solar cell having an indirect transition bandgap.
- [3] However, the compound semiconductor solar cell is under restrictions on the conditions of lattice-matching with a substrate. In particular, the restrictions on the lattice-matching conditions mainly occur in stack-type solar cells, such as tandem solar cells.

Disclosure of Invention

Technical Problem

- [4] Although the tandem solar cell may theoretically achieve an efficiency of about 40% or lower when an upper solar cell and a lower solar cell have energy bandgaps of about 1.5 eV and 0.9 eV, respectively, a variation in energy bandgap leads to a variation in lattice constant due to the characteristics of the material, thereby causing crystalline defects. In particular, the tandem solar cell gives rise to a lattice mismatch with a typical GaAs-based substrate, thereby causing a reliability drop due to the destruction of a solar cell device.

Solution to Problem

- [5] In order to solve the foregoing and/or other problems, it is an object of the present invention to provide a method of fabricating a metamorphic compound semiconductor solar cell using a lattice-mismatched growth technique.
- [6] According to an exemplary embodiment of the present invention, a method of fabricating a metamorphic compound semiconductor solar cell is disclosed. The method includes forming a graded buffer layer having a graded lattice constant from a bottom surface thereof toward a top surface thereof on a support substrate. A sacrificial layer is

formed on the graded buffer layer. A solar cell structure is formed on the sacrificial layer. A support structure is formed on the solar cell structure. The sacrificial layer is selectively etched to separate the solar cell structure from the graded buffer layer. The separated solar cell structure is bonded to a host substrate.

- [7] The lowermost surface of the graded buffer layer may have a lattice match with the support substrate, and the uppermost surface of the graded buffer layer may have a lattice match with a bottom surface of the solar cell structure. The graded buffer layer may include one selected from the group consisting of indium gallium arsenide (InGaAs), indium aluminum arsenide (InAlAs), and indium aluminum phosphide (InAlP). The graded buffer layer may have a graded In content from the bottom surface thereof toward the top surface thereof.
- [8] Before forming the sacrificial layer, a target buffer layer may be further formed on the graded buffer layer. The target buffer layer may have a lattice match with the uppermost surface of the graded buffer layer.
- [9] The sacrificial layer may have a lattice mismatch with the uppermost surface of the graded buffer layer. The sacrificial layer may have a thickness of about 5 nm or less. The sacrificial layer may be an $\text{Al}_x\text{Ga}_{1-x}\text{As}$ ($0.8 \leq x \leq 1$) layer.
- [10] The solar cell structure may be a multi-junction solar cell. The solar cell structure may include a first solar cell, a tunnel junction layer, and a second solar cell, which are sequentially stacked, the first solar cell may absorb an energy of about 0.93 eV to 1.2 eV, and the second solar cell may absorb an energy of about 1.4 eV to 1.7 eV.
- [11] In another case, the solar cell structure may include a single solar cell that absorbs an energy of about 0.36 eV to 1.43 eV.
- [12] The support structure may include an adhesion layer and a support layer, which are sequentially formed on the solar cell structure.
- [13] The separated solar cell structure and the host substrate may be bonded to each other by Van der Waals force.
- [14] After bonding the separated solar cell structure to the host substrate, the support structure may be removed.

Advantageous Effects of Invention

- [15] According to the present invention as described above, the present invention provides a method of fabricating a metamorphic compound semiconductor solar cell in which a hetero-substrate can be bonded to a solar cell structure by adopting a thin-film separation technique using a metamorphic buffer layer.
- [16] Accordingly, in the present invention, an energy absorption layer having a desired combination can be selectively applied, and a volume occupied by a compound semiconductor in the solar cell can be minimized.

Brief Description of Drawings

[17] FIGS. 1 through 5 are cross-sectional views illustrating a method of fabricating a metamorphic compound semiconductor solar cell according to an exemplary embodiment of the present invention.

[18] FIG. 6 is a cross-sectional view of a solar cell structure used for fabrication of a metamorphic compound semiconductor solar cell according to an exemplary embodiment of the present invention.

Mode for the Invention

[19] The detailed features and functions of the present invention will be more clearly understood with reference to the drawings and exemplary embodiments thereof.

[20] The detailed description set forth below in connection with the appended drawings is intended as a description of exemplary embodiments of the invention, and is not intended to represent the only forms in which the present invention may be constructed or utilized. It is to be understood that the same or equivalent functions of the invention set forth herein that may be accomplished by different embodiments are intended to be encompassed within the spirit and scope of this invention. Also, it is to be understood by those skilled in the art that some features shown in the drawings are exaggerated for brevity and the drawings and components are not necessarily illustrated in appropriate proportions. Like reference numerals in the drawings denote like elements, and thus a description thereof will be omitted.

[21] Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the appended drawings.

[22] FIGS. 1 through 5 are cross-sectional views illustrating a method of fabricating a metamorphic compound semiconductor solar cell according to an exemplary embodiment of the present invention, and FIG. 6 is a cross-sectional view of a solar cell structure used for fabrication of a metamorphic compound semiconductor solar cell according to an exemplary embodiment of the present invention.

[23] Referring to FIGS. 5 and 6, a metamorphic compound semiconductor solar cell according to an exemplary embodiment of the present invention may include a solar cell structure 130 disposed on an host substrate 500. In this case, the solar cell structure 130 may include a single solar cell or a stack-type multi-junction solar cell.

[24] When the solar cell structure 130 includes a single solar cell, an absorption energy bandgap of the solar cell structure 130 may range from 0.36 to 1.43 eV or from 0.36 to 1.34 eV depending on the type of a substrate that is initially used for the fabrication of the compound semiconductor solar cell according to the embodiment of the present invention under the restrictions on the conditions of lattice-matching. When the initially used substrate is formed of gallium arsenide (GaAs), the absorption energy

bandgap of the solar cell structure 130 may range from 0.36 eV to 1.43 eV, and when the initially used substrate is formed of indium phosphide (InP), the solar cell structure 130 may range from 0.36 eV to 1.34 eV.

- [25] In addition, when the solar cell structure 130 includes a stack-type multi-junction solar cell, the solar cell structure 130 refers to a stack-type solar cell, such as one of a double-junction solar cell, a triple-junction solar cell, and a quadruple-junction solar cell. However, in the present invention, the number of stacked solar cells is not limited.
- [26] For example, the solar cell structure 130 applied to the compound semiconductor solar cell according to the present embodiment may include a double junction solar cell, which includes a first solar cell 131 disposed on the host substrate 500, a tunnel junction layer 133 disposed on the first solar cell 131, and a second solar cell 135 disposed on the tunnel junction layer 133.
- [27] In this case, the first and second solar cells 131 and 135 may have the same lattice constant. Also, energy absorbable by the second solar cell 135 may be higher than energy absorbable by the first solar cell 131. For example, the absorption energy of the first solar cell 131 may range from 0.93 eV to 1.2 eV, and the absorption energy of the second solar cell 135 may range from 1.4 eV to 1.7 eV.
- [28] Hereinafter, a method of fabricating a compound semiconductor solar cell according to an exemplary embodiment of the present invention will be described with reference to FIGS. 1 through 5.
- [29] Referring to FIG. 1, a buffer layer 110 is formed on a substrate 100. The substrate 100 may be a single crystalline substrate and formed of various compound semiconductor materials. Specifically, the substrate 100 may be formed of one of GaAs and InP, which may be selected according to a solar cell structure 130 to be formed later. For example, when the substrate 100 is formed of GaAs, the first solar cell 131 of the solar cell structure 130 may be formed of indium gallium arsenide (InGaAs). Also, when the substrate 100 is formed of InP, the first solar cell 131 of the solar cell structure 130 may be formed of indium arsenic phosphide (InAsP).
- [30] The buffer layer 110 may be a metamorphic buffer layer, which may have a stacked structure. That is, the buffer layer 110 may include a graded buffer layer 110a serving as a first buffer layer and a target buffer layer 110b serving as a second buffer layer disposed on the graded buffer layer 110a.
- [31] In this case, a lowermost portion of the graded buffer layer 110a may have a lattice match with the substrate 100. Specifically, the lowermost portion of the graded buffer layer 110a may have substantially the same lattice constant as the substrate 100. Also, an uppermost portion of the graded buffer layer 110a may have a lattice match with a lowermost portion of the solar cell structure 130. Specifically, the uppermost portion of the graded buffer layer 110a may have substantially the same lattice constant as the

lowermost portion of the solar cell structure 130. The target buffer layer 110b may have a lattice match with the uppermost portion of the graded buffer layer 110a. Specifically, the target buffer layer 110b may have the same lattice constant as the uppermost portion of the graded buffer layer 110a. In this case, the uppermost portion of the graded buffer layer 110a has a lattice mismatch with the substrate 100. For example, the uppermost portion of the graded buffer layer 110a may have a higher lattice constant than the lowermost portion thereof.

- [32] The buffer layer 110 may include an In-containing ternary compound, for example, one selected from the group consisting of InGaAs, indium aluminum arsenide (InAlAs), indium aluminum phosphide (InAlP), and an equivalent thereof. In this case, the graded buffer layer 110a may be grown while varying an In content. The growth of the graded buffer layer 110a may be started in a low In-content state and stopped at a time point when the In content reaches a desired content, that is, at a time point when the graded buffer layer 110a has substantially the same lattice constant with that of the lowermost portion of the solar cell structure 130.
- [33] A method of growing the graded buffer layer 110a may be classified into a linear method and a nonlinear method. The linear method refers to forming the graded buffer layer 110a such that a degree of lattice mismatch with the substrate 100 is gradually changed (e.g., increased). That is, a variation in the degree of lattice mismatch may be constantly changed over a growth time of the graded buffer layer 110a. The nonlinear method may be categorized as either a convex method or a concave method. The convex method is characterized by sharply varying a lattice constant in an initial stage of the growth of the graded buffer layer 110a. A variation in the degree of lattice mismatch with the substrate 100 is in the form of a square root over time. Unlike the convex method, the concave method is characterized by sharply varying a lattice constant in a final stage of the growth of the graded buffer layer 110a. A variation in the degree of lattice mismatch with the substrate 100 is in the form of a parabola over time. As described above, when the graded buffer layer 110a is formed of an In-containing ternary compound, the lattice constant of the graded buffer layer 110a and the degree of lattice mismatch with the substrate 100 may be changed by gradually varying the In content of the graded buffer layer 110a.
- [34] The target buffer layer 110b may be formed on the graded buffer layer 110a so that the entire target buffer layer 110b can maintain substantially the same composition and lattice constant as the uppermost portion of the graded buffer layer 110a. In this case, the target buffer layer 110b may have a lattice mismatch relationship with the substrate 100. The target buffer layer 110b may be formed to a thickness of about 1 μm or less.
- [35] A sacrificial layer 120 is formed on the buffer layer 110. The sacrificial layer 120 may have a lattice mismatch relationship with the target buffer layer 110b. The sac-

rificial layer 120 having the lattice mismatch relationship with the target buffer layer 110b may prevent crystalline defects, such as dislocation which may occur in the buffer layer 110, from spreading into the solar cell structure 130. The sacrificial layer 120 may be formed to a thickness of about 5 nm or less to suppress the occurrence of the crystalline defects therein. In this case, the spreading of the crystalline defects into the solar cell structure 130 may be prevented once more.

- [36] The sacrificial layer 120 may be an Al-containing compound layer, for example, an Al-containing binary or ternary compound layer. For example, the sacrificial layer 120 may be formed of $\text{Al}_x\text{Ga}_{1-x}\text{As}$ ($1 \geq x \geq 0.8$). This is because a solution obtained by diluting hydrofluoric (HF) acid with deionized (DI) water used as a typical etch solution may effectively etch Al. To this end, the sacrificial layer 120 may be formed of a material having a high Al content. In this case, the selective etching of the sacrificial layer 120 may be further facilitated.
- [37] A solar cell structure 130 having a thin-film shape is formed on the sacrificial layer 120. A material forming the solar cell structure 130 may have substantially the same lattice constant as the uppermost portion of the graded buffer layer 110a or the target buffer layer 110b. Meanwhile, the lattice constant of the material forming the solar cell structure 130 may have a degree of lattice mismatch of about 3% or less with that of the substrate 100.
- [38] The solar cell structure 130 may include a single solar cell formed of a compound semiconductor or a multi-junction solar cell formed of a plurality of compound semiconductors. The multi-junction solar cell refers to a stack-type solar cell, such as a double-junction solar cell, a triple-junction solar cell, and a quadruple-junction solar cell, according to the number of stacked thin-film solar cells, but the present invention is not limited in the number of the stacked thin-film solar cells.
- [39] For example, as shown in FIG. 6, the thin-film solar cell structure 130 may include a double-junction solar cell obtained by stacking two solar cells.
- [40] The double-junction solar cell may include a first solar cell 131 disposed on the sacrificial layer 120, a tunnel junction layer 133 disposed on the first solar cell 131, and a second solar cell 135 disposed on the tunnel junction layer 133.
- [41] In addition, when the multi-junction solar cell is used as the solar cell structure 130, an energy absorption layer of each solar cell may be selectively used. For example, in the case of the double-junction solar cell, the first solar cell 131 may include an energy absorption layer formed using a material with an absorption energy bandgap of about 0.93 eV to 1.2 eV, and the second solar cell 135 may include an energy absorption layer formed using a material with an absorption energy bandgap of about 1.4 eV to 1.7 eV.
- [42] The above-described solar cell structure 130 including the double-junction solar cell

will now be described in detail. To begin with, the first solar cell 131 may include a first-type lower back-surface-field (BSF) layer 131a, a first-type lower base layer 131b, a second-type lower emitter layer 131c, and a second lower front-surface-field (FSF) layer 131d. However, the present invention is not limited thereto, and the first-type lower BSF layer 131a and the second-type lower FSF layer 131d may be omitted. The first-type lower BSF layer 131a may have a greater bandgap than the first-type lower base layer 131b, and the second-type lower FSF layer 131d may have a greater bandgap than the second-type lower emitter layer 131c. Also, a first-type dopant doped into the first-type lower BSF layer 131a may have a higher concentration than a first-type dopant doped into the first-type lower base layer 131b, and a second-type dopant doped into the second-type lower FSF layer 131d may have a higher concentration than a second-type dopant doped into the second-type lower emitter layer 131c.

[43] The second solar cell 135 may include a first-type upper BSF layer 135a, a first-type upper base layer 135b, a second-type upper emitter layer 135c, and a second-type upper FSF layer 135d, which are sequentially stacked. However, the present invention is not limited thereto, and the first-type upper BSF layer 135a and the second-type upper FSF layer 135d may be omitted. The first-type upper BSF layer 135a may have a greater bandgap than the first-type upper base layer 135b, and the second-type upper FSF layer 135d may have a greater bandgap than the second-type upper emitter layer 135c. Also, a first-type dopant doped into the first-type upper BSF layer 135a may have a higher concentration than a first-type dopant doped into the first-type upper base layer 135b. A second dopant doped into the second-type upper FSF layer 135d may have a higher concentration than a second-type dopant doped into the second-type upper emitter layer 135c.

[44] The first type and the second type may be a p type and an n type, respectively, or be an n type and a p type, respectively.

[45] The tunnel junction layer 133 may include a second-type tunnel junction layer 133a and a first-type tunnel junction layer 133b. A second-type dopant doped into the second-type tunnel junction layer 133a may have a higher concentration than a second-type dopant doped into the second-type lower FSF layer 131d disposed adjacent thereto or have a higher concentration than a second-type dopant doped into the second-type lower emitter layer 131c when the second-type lower FSF layer 131d is omitted. Also, a first-type dopant doped into the first-type tunnel junction layer 133b may have a higher concentration than a second-type dopant doped into the first-type upper BSF layer 135a disposed adjacent thereto or have a higher concentration than a second-type dopant doped into the first-type upper base layer 135b when the first-type upper BSF layer 135a is omitted. The tunnel junction layer 133 may prevent the generation and diffusion of a depletion layer due to a p-n junction at an interface

between the first and second solar cells 131 and 135, thereby further facilitating transport of electrons and holes. In other words, since the second-type tunnel junction layer 133a has a high second-type dopant concentration and the first-type tunnel junction layer 133b has a high first-type dopant concentration, a heavily-doped p-n junction may be formed between the first and second solar cells 131 and 135 so that an energy barrier can be reduced to facilitate the transport of electrons and holes.

[46] For example, the first-type lower BSF layer 131a, the first-type lower base layer 131b, the second-type lower emitter layer 131c, and the second-type lower FSF layer 131d may be a p+-type InGaP layer, a p-type InGaAs layer, an n-type InGaAs layer, and an n+-type InGaP layer, respectively. In this case, the first-type lower base layer 131b and the second-type lower emitter layer 131c may have a bandgap of about 0.93 eV, and each of the first-type lower BSF layer 131a and the second-type lower FSF layer 131d may have a bandgap of about 1.41 eV. The first-type upper BSF layer 135a, the first-type upper base layer 135b, the second-type upper emitter layer 135c, and the second-type upper FSF layer 135d may be a p+-type InAlP layer, a p-type InGaP layer, an n-type InGaP layer, and an n+-type InAlP layer, respectively. In this case, the p+-type or n+-type layer may have a heavy doping level of $\sim 10^{18}/\text{cm}^3$, while the p-type or n-type layer may have a moderate doping level of $\sim 10^{17}/\text{cm}^3$. In this case, each of the first-type upper base layer 135b and the second-type upper emitter layer 135c may have a bandgap of about 1.41 eV, and each of the first-type upper BSF layer 135a and the second-type upper FSF layer 135d may have a bandgap of about 1.78 eV. Also, the second-type tunnel junction layer 133a may be an n++-type InGaAs layer, and the first-type tunnel junction layer 133b may be a p++-type InGaAs layer. Materials forming the first solar cell 131, the tunnel junction layer 133, and the second solar cell 135 may have a lattice constant of about 0.5799 nm. When the substrate 100 is formed of GaAs, a degree of lattice mismatch with the substrate 100 may be about 2.6%.

[47] Referring to FIG. 2, a support structure 300 is formed on the solar cell structure 130 to support the solar cell structure 130 and prevent damage to the solar cell structure 130 due to deformation that may occur during a thin-film separation process of the solar cell structure 130.

[48] In this case, the support structure 300 may be a flexible layer and include an adhesion layer 310 and a support layer 320 disposed on the adhesion layer 310. The adhesion layer 310 may have a thickness of several hundreds of nm and include an adhesive polymer, for example, polydimethylglutarimide, to facilitate the adhesion of the adhesion layer 310 to the surface of the solar cell structure 130. Also, the support layer 320 may have a thickness of several μm so as to support the separated solar cell structure 130 and be formed of a polymer, such as rubber and/or bisazide. When the adhesion layer 310 and/or the support layer 320 are polymer layers, the adhesion layer

310 and/or the support layer 320 may be cured through thermal treatment.

[49] Referring to FIG. 3, the sacrificial layer 120 may be etched, thereby separating the solar cell structure 130 from the buffer layer 110 and the substrate 100.

[50] For example, when the sacrificial layer 120 is an Al-containing compound layer, the sacrificial layer 120 may be selectively etched using a solution obtained by diluting 12.5wt% HF acid with DI water so that the solar cell structure 130 can be separated from the buffer layer 110 and the substrate 100. However, the present invention is not limited thereto, and another solution capable of selectively etching the sacrificial layer 120 may be selected according to the kind of the sacrificial layer 120.

[51] After the solar cell structure 130 is separated from the buffer layer 110 and the substrate 100, the substrate 100 on which the buffer layer 110 is formed may be reused to fabricate another solar cell structure 130.

[52] By cleaning the separated solar cell structure 130, the remaining material of the sacrificial layer 120 may be removed. In this case, a cleaning solution may be DI water. During the cleaning process, the solar cell structure 130 may be dipped in DI water so that the material of the sacrificial layer 120 remaining on the surface of the solar cell structure 130 can be removed to clean the surface of the solar cell structure 130.

[53] Referring to FIG. 4, the solar cell structure 130 may be bonded to a host substrate 500. The solar cell structure 130 and the host substrate 500 may be bonded to each other by Van der Waals bonding. To this end, the solar cell structure 130 and the host substrate 500 may be appropriately processed. When the surface of the solar cell structure 130 is coated with the DI water during the cleaning of the solar cell structure 130 and the surface of the host substrate 500 is processed with plasma to have a hydrophilic property, the solar cell structure 130 and the host substrate 500 may be easily bonded to each other.

[54] Referring to FIG. 5, the cleaning solution (i.e., DI water) remaining around the solar cell structure 130 may be evaporated and the support structure 300 may be removed, thereby completing the fabrication of the compound semiconductor solar cell to which a hetero-host substrate 500 is bonded. The removal of the support structure 300 may be performed using a plasma processing method.

[55] In this case, the host substrate 500 may be formed of a material, such as silicon, a ceramic material, a plastic material, or a flexible material, which is different from an initial substrate required for the formation of the solar cell structure 130. Meanwhile, in the present invention, the host substrate 500 is not limited to the above-described materials and may be formed of any material different from the substrate 100.

[56] While the invention has been shown and described with reference to certain exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the

spirit and scope of the invention as defined by the appended claims.

[57]

[58]

Claims

- [Claim 1] A method of fabricating a compound semiconductor solar cell, comprising:
forming a graded buffer layer on a support substrate, the graded buffer layer having a graded lattice constant from a bottom surface thereof toward a top surface thereof;
forming a sacrificial layer on the graded buffer layer;
forming a solar cell structure on the sacrificial layer;
forming a support structure on the solar cell structure;
separating the solar cell structure from the graded buffer layer by selectively etching the sacrificial layer; and
bonding the separated solar cell structure to a host substrate.
- [Claim 2] The method of claim 1, wherein a lowermost surface of the graded buffer layer has a lattice match with the support substrate, and an uppermost surface of the graded buffer layer has a lattice match with a lowermost surface of the solar cell structure.
- [Claim 3] The method of claim 1, wherein the graded buffer layer includes one selected from the group consisting of indium gallium arsenide (InGaAs), indium aluminum arsenide (InAlAs), and indium aluminum phosphide (InAlP).
- [Claim 4] The method of claim 3, wherein the graded buffer layer has a graded indium (In) content from the bottom surface thereof toward the top surface thereof.
- [Claim 5] The method of claim 1, further comprising, before forming the sacrificial layer, forming a target buffer layer on the graded buffer layer.
- [Claim 6] The method of claim 1 or 2, wherein the sacrificial layer has a lattice mismatch with the uppermost surface of the graded buffer layer.
- [Claim 7] The method of claim 1, wherein the sacrificial layer has a thickness of about 5 nm or less.
- [Claim 8] The method of claim 1, wherein the sacrificial layer is an $\text{Al}_x\text{Ga}_{1-x}\text{As}$ ($0.8 \leq x \leq 1$) layer.
- [Claim 9] The method of claim 1, wherein the solar cell structure is a multi-junction solar cell.
- [Claim 10] The method of claim 9, wherein the solar cell structure includes a first solar cell, a tunnel junction layer, and a second solar cell, which are sequentially stacked,
wherein the first solar cell absorbs an energy of about 0.93 eV to 1.2

eV, and

the second solar cell absorbs an energy of about 1.4 eV to 1.7 eV.

[Claim 11]

The method of claim 1, wherein the solar cell structure includes a single solar cell that absorbs an energy of about 0.36 eV to 1.43 eV.

[Claim 12]

The method of claim 1, wherein the support structure includes an adhesion layer and a support layer, which are sequentially formed on the solar cell structure.

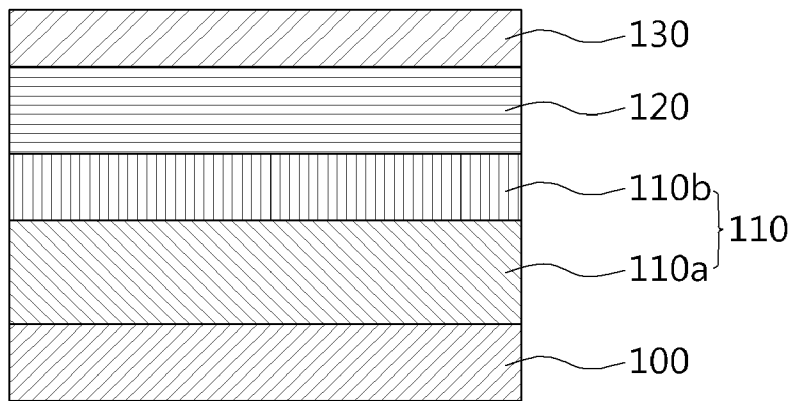
[Claim 13]

The method of claim 1, wherein the separated solar cell structure and the host substrate are bonded to each other by Van der Waals force.

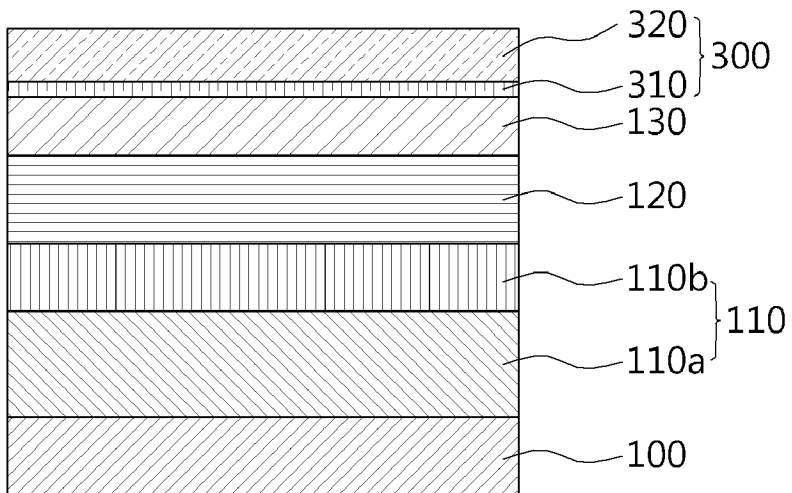
[Claim 14]

The method of claim 1, further comprising, after bonding the separated solar cell structure to the host substrate, removing the support structure.

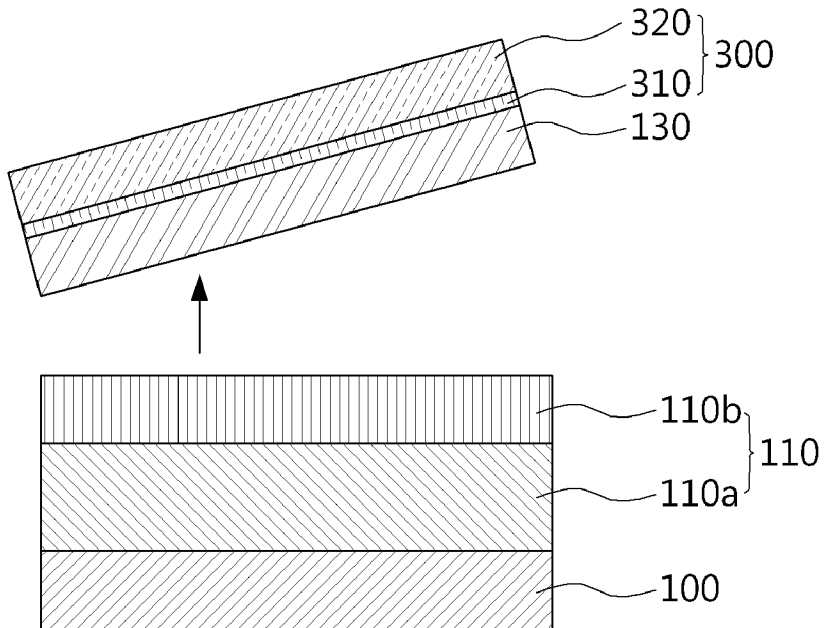
[Fig. 1]



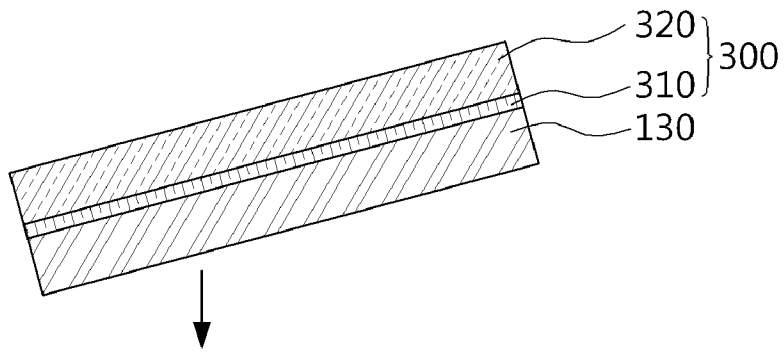
[Fig. 2]



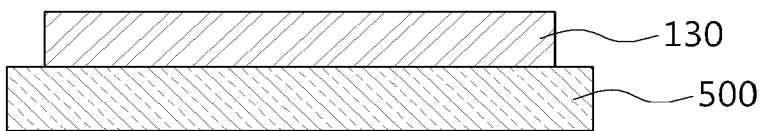
[Fig. 3]



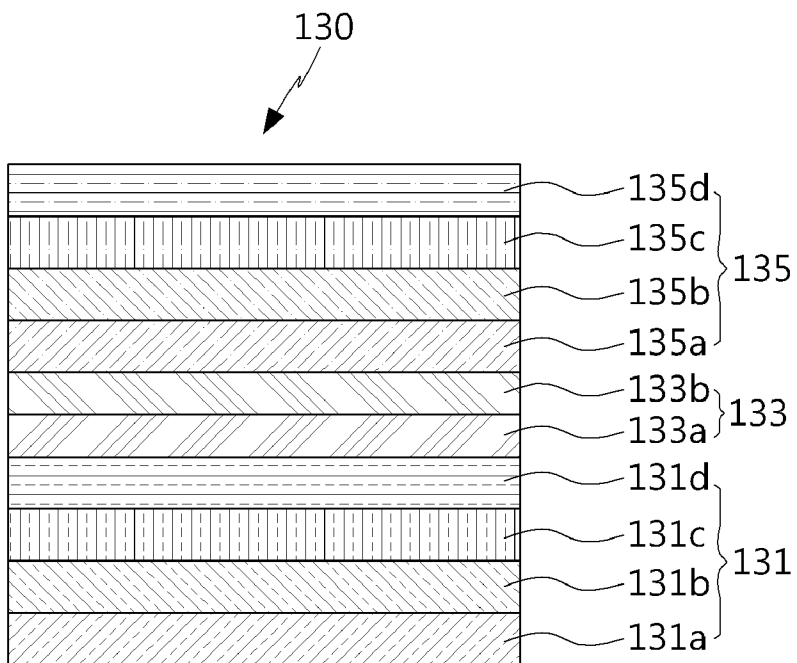
[Fig. 4]



[Fig. 5]



[Fig. 6]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2010/009041**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)

H01L 31/042

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

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: sacrificial , compound, substrate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2009-005825 A1 (MICROLINK DEVICES, INC. et al.) 08 January 2009 See abstract and figures 1-7.	1-14
A	KR 10-0916199 B1 (SAMSUNG ELECTRO-MECHANICS CO., LTD.) 08 September 2009 See abstract and figures 1-10.	1-14

☐ 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

12 AUGUST 2011 (12.08.2011)

Date of mailing of the international search report

16 AUGUST 2011 (16.08.2011)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
Government Complex-Daejeon, 189 Cheongsu-ro,
Seo-gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

KIM Min Soo

Telephone No. 82-42-481-8249



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2010/009041

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2009-005825 A1	08.01.2009	CA 2692126 A1	08.01.2009
		CN 101785115 A	21.07.2010
		CN 101790794 A	28.07.2010
		CN 101790794 A	28.07.2010
		EP 2168171 A1	31.03.2010
		EP 2168172 A1	31.03.2010
		JP 2010-532576 A	07.10.2010
		KR 10-2010-0047246 A	07.05.2010
		KR 10-2010-0049575 A	12.05.2010
		US 2009-038678 A1	12.02.2009
		US 2009-044860 A1	19.02.2009
		WO 2009-005824 A1	08.01.2009
		WO 2009-005825 A8	11.02.2010
KR 10-0916199 B1	08.09.2009	None	