

[0053] 当凸起的阵列图案的截面具有三角形阵列图案或者梯形阵列图案时,凸起的阵列图案可以获得最大透射率。三角形或梯形可以是等腰三角形或等腰梯形。然而,本发明不必局限于此。

[0054] 当三角形或梯形的底角  $\theta$  满足  $45^\circ \pm 5^\circ$  的条件时,能够获得高透射率。特别地,最大透射率可以预计在  $45^\circ$  产生。

[0055] 因此,选择图案的高度,使得底角关于给定间距变成  $45^\circ \pm 5^\circ$ 。当“b”和“c”减小时,透射率预计会增加,并且可以具有 0 值。选择能够制造的最小值。

[0056] 在图 5A 所示的图案中,“b”具有大于 0 的值。在图 5B 所示的图案中,“b”和“c”大于 0。

[0057] 通过减少菲涅尔反射,在衬底 100 的光入射表面上形成的金字塔状阵列图案或者截顶的金字塔状阵列图案起到增加衬底透射率的作用。此外,在光入射表面上形成凸起图案,以便防止衬底 100 受外部环境污染。

[0058] 当金字塔状阵列图案或截顶的金字塔状阵列图案的底角是  $45^\circ \pm 5^\circ$  时,能够获得较高透射率。优选地,在  $45^\circ$  的底角下可以预计获得最高透射率。

[0059] 优选的是,金字塔状阵列图案或截顶的金字塔状阵列图案的高度处于  $80\ \mu\text{m}$  到  $360\ \mu\text{m}$  的范围内。

[0060] 图 7 是示出关于根据本发明实施例的具有金字塔状阵列图案的衬底的透射率通过改变图案高度获得的模拟结果的图。

[0061] 通过使用根据 ISO 标准的 D65 光源 ( $30\text{mm} \times 30\text{mm}$ ) 用光照射碱石灰玻璃 ( $80\text{mm} \times 80\text{mm}$ ) 以及通过使用检测器 ( $160\text{mm} \times 160\text{mm}$ ) 测量透射率,执行透射率测量。这里,配置金字塔状图案,使得金字塔最高点之间的间距是  $200\ \mu\text{m}$  并且相邻金字塔的相邻底部互相连接。

[0062] 如图 7 所示,可以理解,当具有金字塔状阵列图案的衬底的高度处于  $80\ \mu\text{m}$  到  $360\ \mu\text{m}$  的范围内时,衬底具有 93.8% 或 93.8% 以上的高透射率。

[0063] 此外优选的是,配置金字塔状阵列图案或截顶的金字塔状阵列图案,使得雨水等可以容易流下。也就是说,优选的是,金字塔状阵列图案的单元体或截顶的金字塔状阵列图案的单元体限定外部轮廓,使得单元之间的边界具有关于水平方向大于  $0^\circ$  但不超过  $90^\circ$  的倾角。

[0064] 金字塔状阵列图案或截顶的金字塔状阵列图案可以通过展开处理来形成。

[0065] 相关技术领域增加盖板透射率的大多数尝试集中在图案形状或尺寸的细化方面。然而,本发明证明,凸起的阵列图案对透射率的提高可以通过盖板厚度的优化来最大化。

[0066] 虽然将盖板图案的各个部分的形状和尺寸认为仿佛这些形状和尺寸可以多样地改变,但是实际上多种限制使得难以现场改变这样的要素。作为示例,虽然好像设计师可以随意选择凸起的阵列图案的高度,但是能够处理的高度或深度受实际制造场地的条件限制,以及受避免对盖板的耐用性造成不利影响的必要性限制。

[0067] 此外,为了改变图案的各个部分的形状和尺寸,对于设施和环境花费大量成本,因此具有增加盖板和光伏组件的制造成本的问题。

[0068] 相比之下,本发明证明,光透射率可以通过优化凸起的阵列图案和盖板的厚度而

最大化,使得能够在没有上述问题的情况下使透射率和由此产生的光伏效率有利地最大化。

[0069] 当根据本发明实施例的盖板在其上表面上具有上述凸起的阵列图案,同时具有处于 2.9mm 到 3.65mm 范围内的厚度时,该盖板可以具有最大的透射率。

[0070] 图 8 是示出关于图 5B 所示的盖板的透射率通过改变盖板的厚度获得的模拟结果的图。

[0071] 为了测量透射率,使用根据 ISO 标准的 D65 光源 (30mm×30mm) 用光照射碱石灰玻璃盖板 (80mm×80mm),并且使用检测器 (160mm×160mm) 测量透射率。

[0072] 截顶的金字塔状阵列图案形成在盖板上,其中“a”是 371  $\mu\text{m}$ ,”b”是 150  $\mu\text{m}$ ,”c”是 50  $\mu\text{m}$ ,并且图案的高度是 150  $\mu\text{m}$ ,然后通过每次改变盖板的厚度 50  $\mu\text{m}$ ,测量透射率的变化。

[0073] 表 1 给出模拟结果。

[0074] 表 1

[0075]

|         |      |      |      |      |      |      |      |      |
|---------|------|------|------|------|------|------|------|------|
| 厚度 (mm) | 2.9  | 2.95 | 3    | 3.05 | 3.1  | 3.15 | 3.2  | 3.25 |
| T(%)    | 92.7 | 92.9 | 93.1 | 93.3 | 93.6 | 93.9 | 94.0 | 93.9 |
| 厚度 (mm) | 3.3  | 3.35 | 3.4  | 3.45 | 3.5  | 3.55 | 3.6  | 3.65 |
| T(%)    | 93.8 | 93.6 | 93.5 | 93.3 | 93.1 | 92.9 | 92.7 | 92.7 |

[0076] 根据表 1 和图 8( 其将表 3 作为图示出 ),可以理解当盖板的厚度处于 2.9mm 到 3.65mm 范围内时,透射率达到最大。

[0077] 因此,本发明提供其中光入射表面具有凸起的阵列图案的盖板,凸起的阵列图案的截面是三角形或梯形,以及盖板的厚度处于 2.9mm 到 3.65mm 的范围内。这能增加盖板的光透射率,从而使光伏组件的光伏效率最大化。

[0078] 在衬底 100 的光入射表面上形成抗反射膜 200,以便增加入射光的透射率。也就是说,通过使入射到抗反射膜 200 上的光的一些分量(即从抗反射膜反射的光以及从抗反射膜和衬底之间的分界面反射的光)破坏性地互相干扰,抗反射膜 200 增加入射到其上的光的透射率。

[0079] 此外,还可以在衬底 100 的光出射表面上形成抗反射膜 200。

[0080] 根据本发明的实施例,优选的是在 380nm 到 770nm 的波长范围内抗反射膜 200 的折射率处于 1.32 到 1.39 之间。

[0081] 抗反射膜 200 可以通过多种工艺来形成,例如物理气相沉积 (PVD)、化学气相沉积 (CVD)、喷涂、溶胶-凝胶浸渍 (sol-gel dipping) 或蚀刻。

[0082] 因此,通过在具有金字塔状阵列图案或截顶的金字塔状阵列图案的衬底上形成抗反射膜,可以增加用于光伏组件的盖板的透射率。也就是说,与仅形成有金字塔状阵列图案或截顶的金字塔状阵列图案的盖板相比,根据本发明实施例的盖板可以提高大约 3% 到 4% 的透射率,从而增加光伏组件的效率。

[0083] 图 9A 是示出各个抗反射膜的折射率随 380nm 到 770nm 波长范围内的波长变化的

图,并且图 9B 是示出平坦衬底(没有图案和抗反射膜)、图案化的衬底(没有抗反射膜)以及在光出射表面和图案化的光入射表面上具有图 9A 的抗反射膜的盖板的透射率的图。这里,衬底由碱石灰玻璃制成。参考图 9B,能够理解,根据本发明实施例的盖板的透射率是 97.4%或 97.4%以上,这高于平坦衬底的透射率以及图案化衬底的透射率。

[0084] 下面的表 2 给出具有图 9A 所示抗反射膜平坦衬底的透射率,以及具有图 9A 所示抗反射膜的图案化盖板的透射率。

[0085] 表 2

[0086]

|        | 在两个表面上具有抗反射膜的平坦衬底的透射率(%) | 在两个表面上具有抗反射膜的图案化盖板的透射率(%) |
|--------|--------------------------|---------------------------|
| 抗反射膜 1 | 97.0                     | 97.6                      |
| 抗反射膜 2 | 97.2                     | 97.4                      |
| 抗反射膜 3 | 97.4                     | 97.8                      |
| 抗反射膜 4 | 97.8                     | 98.3                      |

[0087] 上面表 2 的透射率是通过下列模拟获得的。1) 首先,在光秃的玻璃板(由碱石灰玻璃制成)上放置抗反射膜;2) 然后,计算随所放置的抗反射膜而定的透射率(表 2 的第二列);3) 然后,根据波长反向计算随所放置的抗反射膜而定的折射率(图 9A);4) 绘出图案;5) 在图案化的表面上放置具有根据波长的折射率(图 9A)的抗反射膜;6) 计算图案化的盖板的透射率(表 2 的第三列)。

[0088] 如从表 2 中可看出的,能够理解,根据本发明实施例的涂覆有抗反射膜的图案化衬底比涂覆有抗反射膜平坦衬底提高 0.2%到 0.6%的透射率。

[0089] 在 380nm 到 770nm 的波长范围内,优选的是根据波长的折射率处于 1.32 到 1.39 的范围内。当根据波长的折射率超过 1.39 时,盖板的透射率不符合要求,这是成问题的。当根据波长的折射率小于 1.32 时,形成具有低于 1.32 的折射率的抗反射膜是不容易的。

[0090] 图 10 是示出平坦衬底(没有图案和抗反射膜)、图案化的衬底(没有抗反射膜)和在图案化的光入射表面上具有图 9A 的抗反射膜 1 的盖板的透射率的图。

[0091] 如从图 10 中看到的,可以理解对于可见光范围内的所有波长,根据本发明实施例的盖板的透射率高于平坦衬底的透射率以及图案化的衬底的透射率。

[0092] 已经关于某些实施例和附图呈现了本发明的具体示例性实施例的上面描述。它们不是旨在全面的或者将本发明局限于所公开的精确形式。显而易见地,具有本领域普通技能的人员按照上面教导可以进行多种修改和变型。

[0093] 因此,希望本发明的范围不局限于上述实施例,而是由所附权利要求和它们等价物来限定。

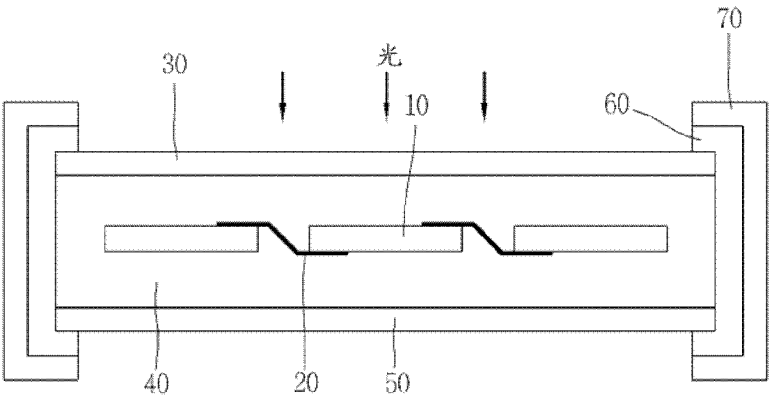


图 1

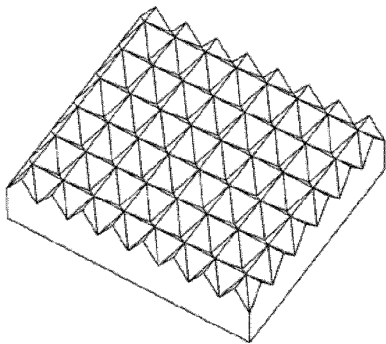


图 2A



图 2B

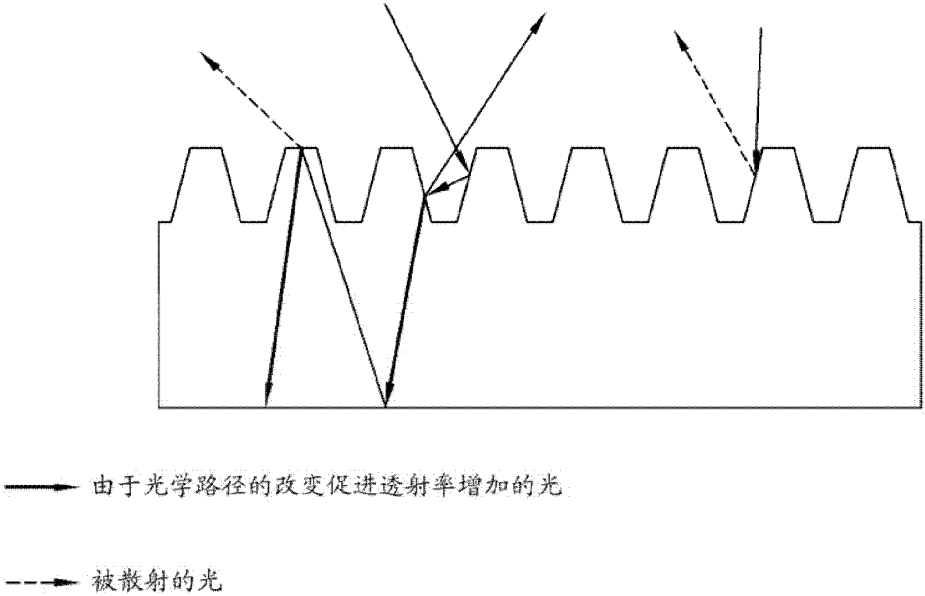


图 3

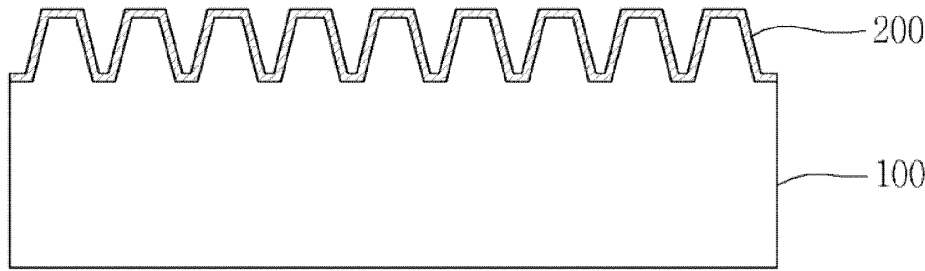


图 4

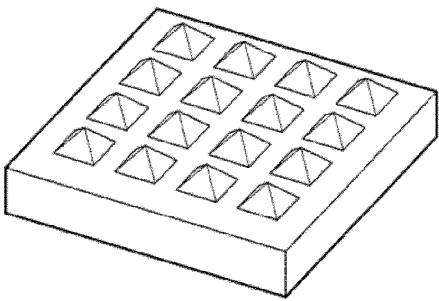


图 5A

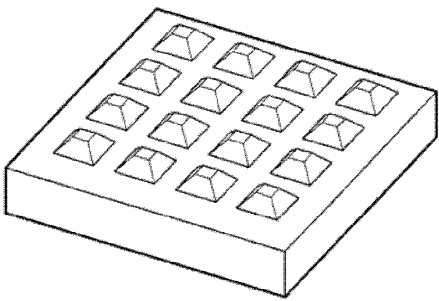


图 5B

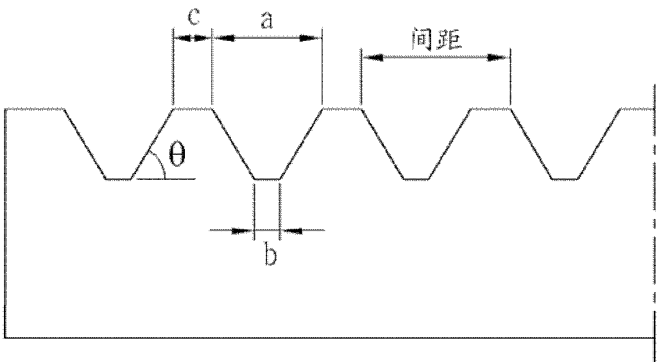


图 6

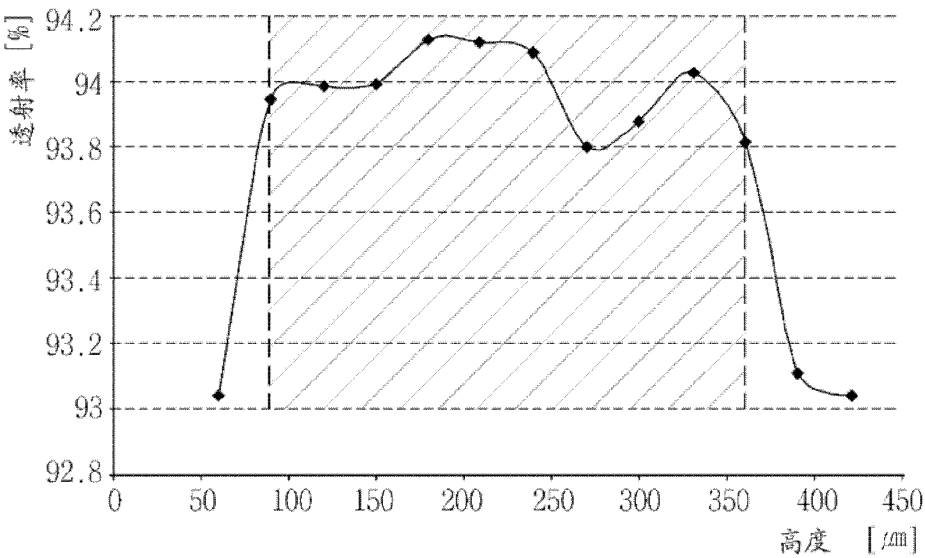


图 7

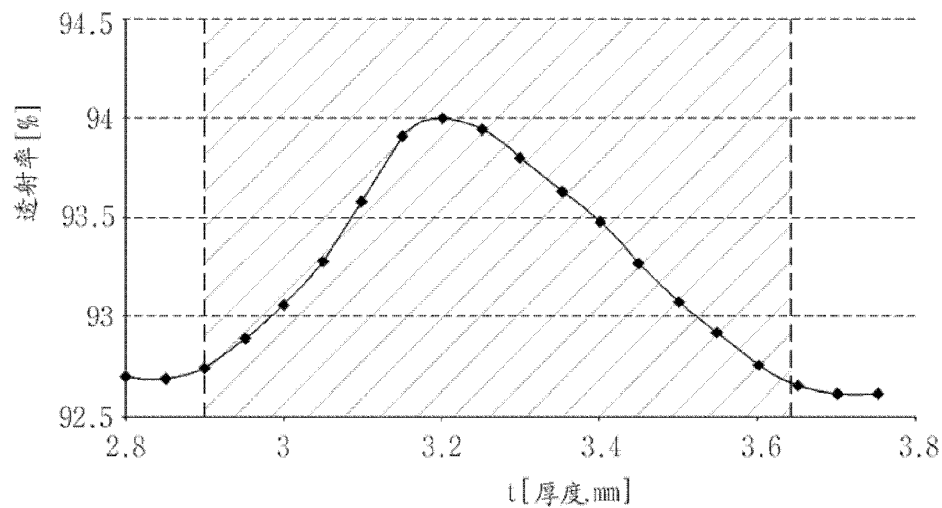


图 8

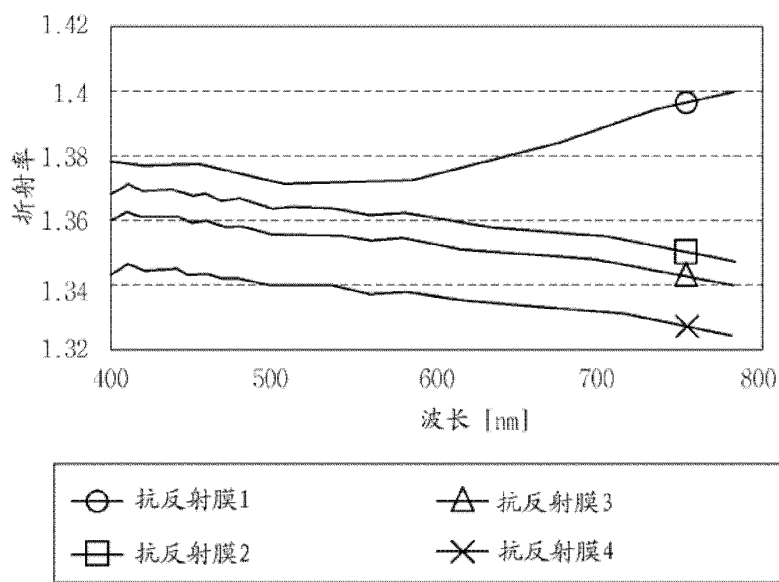


图 9A

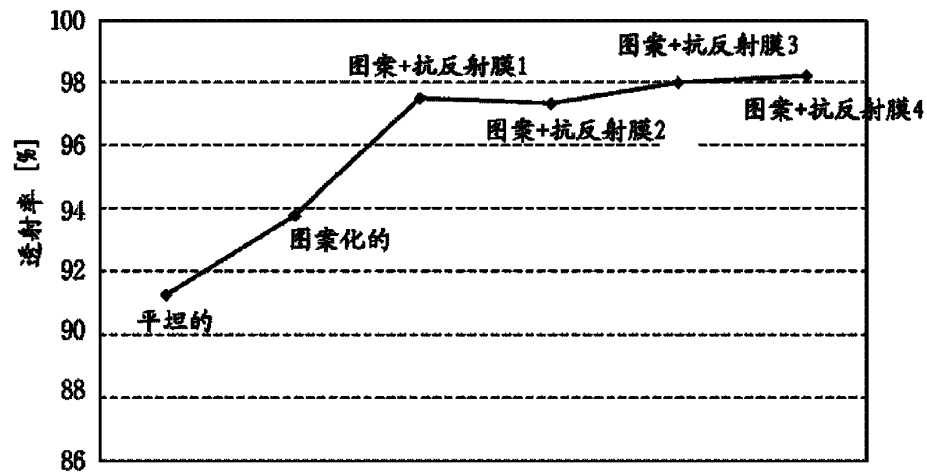


图 9B

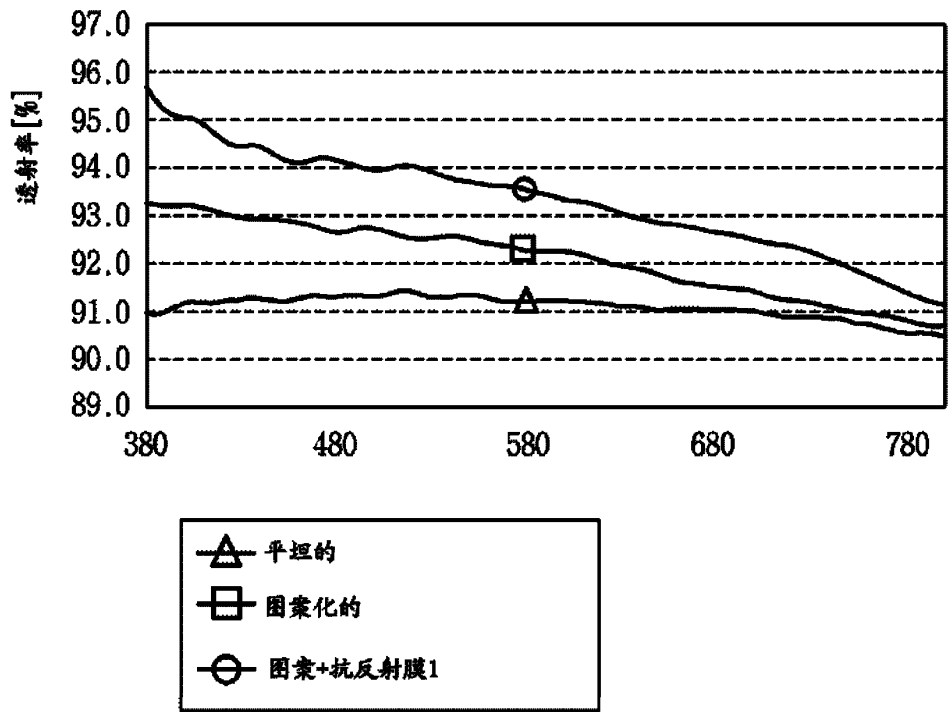


图 10



Espacenet

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Solar cell and method for manufacturing same

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### Abstract of CN104350607 (A)

The purpose of the present invention is to provide a solar cell, which suppresses generation of defects, and which has high photoelectric conversion efficiency. This solar cell is provided with: a silicon substrate formed of a single crystal or the like of an n-type single crystal silicon substrate (1) having pyramid-shaped recessed and projecting sections (P) formed thereon; and an amorphous or fine crystal semiconductor layer, which is film-formed on the single crystal silicon substrate. Flat portions (F) are formed at the valley parts of the pyramid-shaped recessed and projecting sections (P) that are provided on the surface of the single crystal silicon substrate. With such configuration, a sharp angle of 70-85 degrees of the recessed sections formed of substantially a (111) plane can be widened to 115-135 degrees. Consequently, an atomic step-shaped shape change due to a rounded shape can be eliminated, and epitaxial growing and defects in the amorphous or fine crystal semiconductor layer can be suppressed.

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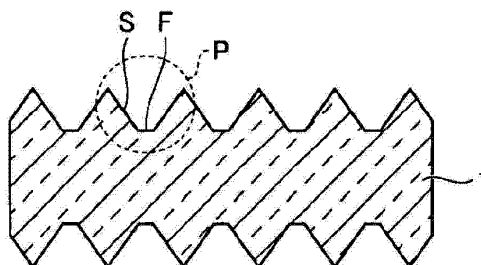
权利要求书2页 说明书13页 附图11页

(54) 发明名称

太阳能电池及其制造方法

(57) 摘要

目的在于得到一种抑制缺陷的产生、光电变换效率高的太阳能电池。该太阳能电池具备形成有金字塔状的凹凸部P的n型单晶硅基板1的单晶体等的硅基板、和在该单晶硅基板上形成的非晶质或者微晶半导体层,在所述单晶硅基板的表面设置的金字塔状的凹凸部P的谷部形成了平坦部F。通过该结构,能够使由大致(111)面形成的70~85°的陡峭的凹部角度广角化为115~135°。因此,能够消除由倒角形状所引起的原子台阶状的形状变化,能够抑制非晶质或者微晶半导体层中的外延生长以及缺陷。



CN 104350607 A

1. 一种晶体系太阳能电池,在第一导电类型的晶体系硅基板的表面形成有第二导电类型的半导体层,其中在该第一导电类型的晶体系硅基板的表面形成有大量金字塔状的凹凸部,该太阳能电池的特征在于,

在所述晶体系硅基板的表面设置的金字塔状的凹凸部的谷部具有平坦部。

2. 根据权利要求1所述的太阳能电池,其特征在于,

所述金字塔状的凹凸部是在第一导电类型的晶体系硅基板的(100)表面重叠地配置金字塔状的凸部而构成的。

3. 根据权利要求1所述的太阳能电池,其特征在于,

所述金字塔状的凹凸部是规则地排列逆金字塔状的凹部而构成的。

4. 根据权利要求1~3中的任意一项所述的太阳能电池,其特征在于,

所述晶体系硅基板是单晶硅基板。

5. 根据权利要求1~4中的任意一项所述的太阳能电池,其特征在于,

所述第二导电类型的半导体层是非晶质或者微晶半导体层。

6. 根据权利要求1~5中的任意一项所述的太阳能电池,其特征在于,

所述凹凸部的谷部的平坦部的一边为600nm以下。

7. 根据权利要求6所述的太阳能电池,其特征在于,

所述第二导电类型的半导体层是通过CVD法形成的非晶质或者微晶半导体层。

8. 根据权利要求6所述的太阳能电池,其特征在于,

所述第二导电类型的半导体层是通过杂质扩散形成的,

在所述第二导电类型的半导体层的表面形成了电介体层。

9. 根据权利要求8所述的太阳能电池,其特征在于,

所述电介体层由氮化硅、氧化硅、或氧化铝中的某一个、或者包含至少一个的材料构成。

10. 一种太阳能电池的制造方法,包括:

在第一导电类型的晶体硅系基板表面形成纹理构造的工序;以及

在所述晶体系硅基板表面形成第二导电类型的半导体层的工序,

其特征在于,

形成所述纹理构造的工序包括:

第一工序,实施各向异性蚀刻,形成所述金字塔型的凹凸部;

第二工序,实施各向同性蚀刻,对所述金字塔型的凹凸部的角部附加倒角;以及

第三工序,实施各向异性蚀刻,在所述金字塔型的凹凸部的谷部形成平坦部。

11. 根据权利要求10所述的太阳能电池的制造方法,其特征在于,

形成所述纹理构造的工序是

不形成抗蚀刻膜,而直接对第一导电类型的晶体系硅基板的(100)表面实施蚀刻,形成重叠地配置了金字塔状的凸部的凹凸部的工序。

12. 根据权利要求10所述的太阳能电池的制造方法,其特征在于,

形成所述纹理构造的工序包括:

在所述晶体系硅基板的表面,形成具有以一定间隔规则地排列的开口部的抗蚀刻膜的工序;

第一工序,将所述抗蚀刻膜作为掩模,实施各向异性蚀刻,形成多个逆金字塔型的凹凸部;

第二工序,实施各向同性蚀刻,对逆金字塔型的凹凸部的角部附加倒角;以及

第三工序,实施各向异性蚀刻,在所述逆金字塔型的凹凸部的谷部形成平坦部。

13. 根据权利要求 10 ~ 12 中的任意一项所述的太阳能电池的制造方法,其特征在于,所述晶体硅系基板是单晶硅基板。

14. 根据权利要求 10 ~ 13 中的任意一项所述的太阳能电池的制造方法,其特征在于,形成所述第二导电类型的半导体层的工序是在具有所述纹理构造的基板表面形成非晶质或者微晶半导体层的工序。

15. 根据权利要求 10 ~ 14 中的任意一项所述的太阳能电池的制造方法,其特征在于,所述第三工序是进行各向异性蚀刻以使所述凹凸部的谷部的平坦部的一边成为 600nm 以下的工序。

16. 根据权利要求 10 所述的太阳能电池的制造方法,其特征在于,所述第二工序是将至少包含氢氟酸和硝酸的混合溶液用作蚀刻液的蚀刻工序,所述第三工序是将碱性水溶液用作蚀刻液的蚀刻工序。

17. 根据权利要求 14 所述的太阳能电池的制造方法,其特征在于,形成所述第二导电类型的半导体层的工序是通过 CVD 法形成非晶质或者微晶半导体层的工序。

18. 根据权利要求 15 所述的太阳能电池的制造方法,其特征在于,形成所述第二导电类型的半导体层的工序是杂质扩散工序,还包括在所述第二导电类型的半导体层的表面形成电介体层的工序。

19. 根据权利要求 18 所述的太阳能电池的制造方法,其特征在于,形成所述电介体层的工序是包括 CVD 工序,形成由氮化硅、氧化硅、或氧化铝中的某一个、或者包含至少一个的材料构成的膜的工序。

## 太阳能电池及其制造方法

### 技术领域

[0001] 本发明涉及太阳能电池及其制造方法,特别涉及使用了具有构成防反射构造的纹理构造的晶体系的硅基板的太阳能电池及其制造方法。

### 背景技术

[0002] 在将入射的光通过光电变换部变换为电的太阳能电池中,如果表面的光反射大,则入射到太阳能电池内部的光减少,得到的电力也变少。因此,为了提高太阳能电池的光电变换效率,重要的是降低表面的光反射率,取入更大量的光。为了降低光反射率,有效的是在例如太阳能电池的表面设置反射防止膜。

[0003] 然而,即使使用反射防止膜,也产生入射光的几%的反射所致的损失,所以还在太阳能电池的表面形成被称为纹理的微小的凹凸,实现由于陷光效应(optical confinement effect)所致的反射率降低。

[0004] 例如,关于单晶硅,通过使用碱性溶液来进行各向异性蚀刻,能够容易地形成随机的金字塔形状的凹凸构造作为纹理。通过这些方法,能够大幅降低太阳能电池的表面的光反射率,但作为实现进一步降低反射率的方法,已知规则地配置有金字塔型的开口部的纹理构造。作为金字塔型的开口部的制造方法,已知在单晶硅的表面形成蚀刻掩模,隔着该蚀刻掩模进行各向异性蚀刻的方法。这样,通过在受光面规则地设置金字塔型的纹理,相比于随机地设置的纹理,能够进一步提高多重散射所致的陷光效应。

[0005] 以往,在使用单晶硅基板等晶体系硅基板的太阳能电池中,通过各向异性蚀刻对硅(100)基板的表面进行蚀刻,从而形成起因于(111)面的金字塔状的凹凸形状(纹理)。

[0006] 另一方面,公开了在单晶硅基板上层叠非晶硅层或者微晶硅层,形成了PN结的异质结型太阳能电池技术(专利文献1)。然而,在这样的异质结构造中,存在在异质结界面大量地产生缺陷、得不到高变换效率这样的问题。因此,公开了在单晶硅基板与非晶硅基板之间夹持薄的本征非晶硅层,而降低了异质结界面中的缺陷的构造的太阳能电池技术(专利文献2)。

[0007] 在上述那样的太阳能电池构造中,由于形成于硅基板的金字塔状的陡峭的凹凸形状,存在在基板上形成的非晶硅层产生缺陷、或者产生膜厚的不均匀性这样的问题,导致输出特性降低。因此,在专利文献3中,公开了对带金字塔状凹凸的基板实施各向同性蚀刻处理,对谷部设置倒角,从而解决上述问题的技术。

[0008] 现有技术文献

[0009] 专利文献

[0010] 专利文献1:日本特开昭59-175170号公报

[0011] 专利文献2:日本特公平7-95603号公报

[0012] 专利文献3:日本专利第3271990号公报

### 发明内容

[0013] 发明所要解决的技术问题

[0014] 然而,作为深入研究的结果,发现即使如专利文献3那样对纹理的谷附加倒角,有时也不能提高性能。这是由于通过对纹理的谷的底部形状附加倒角,出现原子台阶(step)上的形状变化,所以在纹理底部,非晶硅层易于外延生长。另外,认为由于在底部出现(100)面,所以非晶硅层易于外延生长,易于形成缺陷。因此,本发明的目的在于得到一种能够再现性良好地降低纹理构造的谷的形状所引起的特性劣化的太阳能电池及其制造方法。

[0015] 解决技术问题的技术方案

[0016] 为了解决上述课题并达到目的,本发明提供一种晶体系太阳能电池,在第一导电类型的晶体系硅基板的表面形成第二导电类型的半导体层,其中在该第一导电类型的晶体系硅基板的表面形成有大量金字塔状的凹凸部,该太阳能电池的特征在于,在所述晶体系硅基板的表面设置的金字塔状的凹凸部的谷部具有平坦部。

[0017] 发明效果

[0018] 根据本发明,由于使得在金字塔状的凸部的谷部具有平坦部,所以起到能够比以现有的技术提高开路电压( $V_{oc}$ )以及曲线因子(F.F.)、能够降低晶体太阳能电池的谷的形状所引起的特性劣化、提高输出特性这样的效果。

#### 附图说明

[0019] 图1是本发明的实施方式1的晶体系硅太阳能电池的概略结构图。

[0020] 图2-1是本发明的实施方式1的晶体系硅太阳能电池的n型单晶硅基板的截面影像图。

[0021] 图2-2是本发明的实施方式1的晶体系硅太阳能电池的n型单晶硅基板的平面影像图。

[0022] 图3是示出本发明的实施方式1的晶体系硅太阳能电池的n型单晶硅基板的谷部截面TEM像的图。

[0023] 图4是说明本发明的实施方式1的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的n型单晶硅基板的纹理形成工序的步骤的流程图。

[0024] 图5-1是说明本发明的实施方式1的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的n型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0025] 图5-2是说明本发明的实施方式1的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的n型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0026] 图5-3是说明本发明的实施方式1的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的n型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0027] 图5-4是说明本发明的实施方式1的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的n型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0028] 图6-1是示出使用了具有该纹理构造的n型单晶硅基板的本发明的实施方式1的晶体系硅太阳能电池的制造工序的工序截面图。

[0029] 图6-2是示出使用了具有该纹理构造的n型单晶硅基板的本发明的实施方式1的晶体系硅太阳能电池的制造工序的工序截面图。

[0030] 图6-3是示出使用了具有该纹理构造的n型单晶硅基板的本发明的实施方式1的

晶体系硅太阳能电池的制造工序的工序截面图。

[0031] 图 6-4 是示出使用了具有该纹理构造的 n 型单晶硅基板的本发明的实施方式 1 的晶体系硅太阳能电池的制造工序的工序截面图。

[0032] 图 6-5 是示出使用了具有该纹理构造的 n 型单晶硅基板的本发明的实施方式 1 的晶体系硅太阳能电池的制造工序的工序截面图。

[0033] 图 7 是通过各向异性蚀刻实施了凹凸加工的晶体硅基板的平面影像图。

[0034] 图 8 是示出通过各向异性蚀刻形成的金字塔状凹凸部的谷部截面 TEM 像的图。

[0035] 图 9 是示出在通过各向异性蚀刻形成的金字塔状凹凸部实施了各向同性蚀刻的情况下的谷部截面 TEM 像的图。

[0036] 图 10-1 是示出本发明的实施方式 1 的归一化反射率和归一化  $V_{oc}$  的关系的曲线图。

[0037] 图 10-2 是示出本发明的实施方式 1 的谷部平坦部长和归一化  $V_{oc}$  的关系的曲线图。

[0038] 图 11-1 是示出使用了具有该纹理构造的 p 型单晶硅基板的本发明的实施方式 2 的晶体系硅太阳能电池的制造工序的工序截面图。

[0039] 图 11-2 是示出使用了具有该纹理构造的 p 型单晶硅基板的本发明的实施方式 2 的晶体系硅太阳能电池的制造工序的工序截面图。

[0040] 图 11-3 是示出使用了具有该纹理构造的 p 型单晶硅基板的本发明的实施方式 2 的晶体系硅太阳能电池的制造工序的工序截面图。

[0041] 图 12-1 是本发明的实施方式 3 的晶体系硅太阳能电池的 n 型单晶硅基板的截面影像图。

[0042] 图 12-2 是本发明的实施方式 3 的晶体系硅太阳能电池的 n 型单晶硅基板的平面影像图。

[0043] 图 13 是说明本发明的实施方式 3 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的流程图。

[0044] 图 14-1 是说明本发明的实施方式 3 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0045] 图 14-2 是说明本发明的实施方式 3 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0046] 图 14-3 是说明本发明的实施方式 3 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0047] 图 14-4 是说明本发明的实施方式 3 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0048] 图 14-5 是说明本发明的实施方式 3 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0049] 图 14-6 是说明本发明的实施方式 3 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的工序截面图。

[0050] 符号说明

[0051] 1 : n 型单晶硅基板 ; 1p : p 型单晶硅基板 ; 2a、2b : i 型非晶硅层 ; 3 : p 型非晶硅层 ;

3d : n 型硅扩散层 ; 4 : n 型非晶硅层 ; 5a、5b : 透光性电极 ; 6 : 集电极 ; 7 : 背面电极 ; 8 : 电介质膜 ; P : 凹凸部 ; F : 平坦部 ; S : 侧面 ; 15 : p 型硅扩散层 ; 16 : 受光面侧电极 ; 17 : 背面电极。

### 具体实施方式

[0052] 以下, 根据附图, 详细说明本发明的太阳能电池及其制造方法的实施方式。另外, 本发明不限于以下的记述, 能够在不脱离本发明的要点的范围内适当地变更。另外, 在以下所示的附图中, 为易于理解, 各部件的比例尺有时与实际不同。在各附图之间也是同样的。

[0053] 实施方式 1.

[0054] 图 1 是示出本发明的太阳能电池的实施方式 1 的晶体系硅太阳能电池的概略结构的图。图 2-1、图 2-2 是示出作为构成该太阳能电池的晶体系硅基板的、n 型单晶硅基板 1 的截面影像图、以及平面影像图的图。在该硅太阳能电池中, 作为晶体系的硅基板, 使用了电阻率是  $1 \sim 10 \Omega \cdot \text{cm}$ , 主表面由 (100) 面构成, 厚度是  $50 \mu\text{m}$  以上且  $300 \mu\text{m}$  以下的 n 型单晶硅基板 1。在该 n 型单晶硅基板 1 的表面, 随机地排列了大量谷部的顶点构成平坦部 F 的金字塔状的凹凸部 P。该凹凸部 P 成为在谷部具有平坦部 F 的金字塔状, 成为在金字塔形状具有的 4 个底边中的 3 边以上具有平坦部 F 的结构。S 表示金字塔状的凸部的侧面。该 n 型单晶硅基板 1 的表面具有凹凸部 P, 但实际上, 可以认为是在 (100) 表面重叠地配置了金字塔状的凸部的结构。

[0055] 另外, 在形成了该纹理的 n 型单晶硅基板 1 的两侧的表面, 形成了 i 型的非晶硅层 2a、2b。在 i 型非晶硅层 2a 上, 形成厚度为约 5nm 的 p 型非晶硅层 3。在 i 型非晶硅层 2b 上, 形成厚度为约 5nm 的 n 型非晶硅层 4。此处, i 型非晶硅层 2a、2b 对修复基板表面的缺陷来提高光电变换效率发挥作用。另外, 隔着 i 型非晶硅层 2b 形成的 n 型非晶硅 4 是用于高效地捕获产生的载流子的 BSF (Back Surface Field, 背面电场) 层, 但不是一定必须形成这些 i 型非晶硅层 2a、2b 以及 n 型非晶硅 4。另外, 关于纹理构造, 也可以仅形成于受光面侧。

[0056] 另外, 在 p 型非晶硅层 3 上, 形成了厚度为约 70nm 的 ITO (氧化铟锡) 等透光性电极 5a, 在所述透光性电极 5a 上, 形成了由银 (Ag) 构成的厚度为约  $60 \mu\text{m}$  的集电极 6。另一方面, 在 n 型非晶硅层 4 上, 隔着透光性电极 5b, 在整个面形成了厚度约 300nm 的由银 (Ag) 构成的背面电极 7。

[0057] 图 2-1 示出本发明的实施方式 1 的经凹凸加工的 n 型单晶硅基板 1 的截面影像图, 图 2-2 示出平面影像图。另外, 图 3 示出该 n 型单晶硅基板 1 的谷部的截面 TEM 像。如图 2-1 以及图 2-2 所示, 可知在大致所有的、以四角锥为基本的纹理构造的凹凸部 P 的谷部的底部之间的间隙, 形成微细的宽度的平坦部 F, 换言之, 可知大部分的纹理的谷部的 4 边被细的平坦部包围。此处, 平坦部 F 是用粗线表示的区域。另外, 根据图 3 能够确认, 通过在 n 型单晶硅基板 (硅基板) 1 的谷部形成平坦部 F, 凹部角度被广角化为  $115 \sim 135^\circ$ , 并且, 未形成原子台阶状的形状变化。另外, 此处, M 是观察用的保护膜。

[0058] 接下来, 说明本发明的实施方式 1 的晶体系硅太阳能电池的制造方法。图 4 是说明本发明的实施方式 1 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的流程图。图 5-1 ~ 图 5-4 是说明本发明的实施方式 1 的晶体系硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理

形成工序的步骤的工序截面图。图 6-1 ~ 图 6-5 是示出使用了具有该纹理构造的 n 型单晶硅基板的晶体系硅太阳能电池的制造工序的工序截面图。

[0059] 在本实施方式的太阳能电池的制造方法中,不形成抗蚀刻膜,而直接在第一导电类型的晶体系硅基板的 (100) 表面实施蚀刻,形成在 (100) 表面重叠地配置了金字塔状的凸部的纹理。即,其特征在于,形成纹理构造的工序包括:第一工序(步骤 S30),对硅基板的表面实施各向异性蚀刻,形成多个金字塔型的凹凸部;第二工序(步骤 S40),实施各向同性蚀刻,对金字塔型的凹凸部的角部附加倒角;以及第三工序(步骤 S50),接下来实施各向异性蚀刻,在所述金字塔型的凹凸部的谷部形成平坦部。

[0060] 首先,作为基板,准备主面的晶面取向(crystal face orientation)为 (100) 的 n 型单晶硅基板 1(图 5-1)。n 型单晶硅基板 1 是从掺杂成期望的浓度的 n 型的单晶硅锭用多线锯切片而得到的。

[0061] 接下来,对 n 型单晶硅基板 1 的受光面侧的表面实施各向异性蚀刻。在该各向异性蚀刻中,例如,将包含适量的有机物的碱性溶液供给到 n 型单晶硅基板 1 的表面。作为碱性溶液,使用例如氢氧化钠(NaOH)水溶液、氢氧化钾(KOH)水溶液等。这些水溶液的浓度根据添加的有机物的种类而适当地变更,而例如碱浓度优选为 1 重量%以上且 10 重量%以下,作为有机物,也可以使用例如异丙醇(IPA)等醇、有机磺酸、有机酯等,也可以添加界面活性剂、醚等。另外,蚀刻时的这些水溶液的温度优选为 70℃ 以上且 90℃ 以下。蚀刻时间优选为 20 ~ 40 分钟。通过添加磺酸,能够实现表面的平滑化。

[0062] 如果通过碱性水溶液对 n 型单晶硅基板 1 的表面进行各向异性蚀刻,则在蚀刻速度快的 (100) 面等中蚀刻进展,如果形成仅由蚀刻速度极其慢的 (111) 面构成的凹凸部 P,则蚀刻的进展变慢。这样,形成金字塔型的凹凸部 P(步骤 S30、图 5-2)。图 5-2 示出形成了具有晶面取向为 (111) 的斜面的金字塔型的凹凸部 P 的状态。

[0063] 该金字塔型的凹凸部 P 具有晶面取向为 (111) 的斜面。金字塔型的凹凸部 P 是在将 n 型单晶硅基板 1 的受光面设为上侧时形成四角锥形状的突出部的结构,俯视时成为正方形形状,也被称为金字塔型构造。各金字塔型的凹凸部 P 是 4 个斜面交叉而形成的,其底部形成凹部形状的最深部 E。

[0064] 像这样,如图 5-2 所示,进行表面加工,以使得在 n 型单晶硅基板 1 的表面具有由被称为纹理的大致 (111) 面形成的金字塔状的凹凸部 P。图 7 示出此时的经凹凸加工的 n 型单晶硅基板 1 的平面影像图,图 8 示出纹理谷部的 TEM 像。此时,由 (111) 面构成 70 ~ 85° 的陡峭的截面 V 字状的槽。在蚀刻中,也可以搅拌蚀刻溶液。另外,在该例子中,在 n 型单晶硅基板 1 的受光面侧以及背面侧这两面形成了凹凸部 P,但也可以仅在受光面侧形成凹凸部 P。另外,还有根据纹理,形成被称为逆金字塔构造的凹凸部 P 的方法,本实施方式的方法对于带逆金字塔构造的纹理的基板也是有效的。另一方面,也可以在形成凹凸部 P 之前,为了抑制蚀刻不均,实施基板的收纳清洗(initial cleaning)。进而,也可以实施使用了酸性或者碱性溶液的湿法蚀刻来去除切片时的基板表面的损伤层的工序。另外,在损伤层去除工序之后,期望为了提高性能而实施基板内杂质的吸气处理。作为吸气处理,使用磷扩散处理等。

[0065] 接下来,如图 5-3(步骤 S40)所示,对形成有凹凸部 P 的 n 型单晶硅基板 1 实施各向同性蚀刻,在谷部形成倒角。图 9 示出此时的纹理谷部的 TEM 像。平面影像图与图 2-2

相同。作为各向同性蚀刻溶液,能够使用氢氟酸(HF)和硝酸( $\text{HNO}_3$ )的混合液、或者氢氟酸(HF)、硝酸( $\text{HNO}_3$ )以及醋酸( $\text{CH}_3\text{COOH}$ )的混合液等。由于通过调整浓度或者处理时间,能够控制谷部倒角形状,所以对浓度或者处理时间的条件不作限定。在将例如氢氟酸(HF)和硝酸( $\text{HNO}_3$ )以1:10~1:100的比例混合的水溶液中,将形成有所述凹凸部P的n型单晶硅基板1浸渍10秒~5分钟为好。在蚀刻中,也可以搅拌蚀刻溶液。另外,各向同性蚀刻不限于湿法蚀刻,还能够通过干法蚀刻进行。

[0066] 进而,对形成有谷部被倒角了的凹凸部P的n型单晶硅基板1,实施短时间的各向异性蚀刻处理,在谷部形成平坦部F(步骤S50)。像这样,得到如图5-4所示形成有在谷部具有平坦部F的凹凸部P的n型单晶硅基板1。

[0067] 在本实施方式中,新发现如下这样的现象:通过进行碱性蚀刻,倒角了的谷部成为平坦形状。作为各向异性蚀刻溶液,期望使用氢氧化钠(NaOH)以及氢氧化钾(KOH)等碱金属氢氧化物的水溶液、碳酸钠( $\text{Na}_2\text{CO}_3$ )以及碳酸钾( $\text{K}_2\text{CO}_3$ )等碱金属碳酸盐的水溶液。例如,在常温的0.1~15wt%的氢氧化钠(NaOH)水溶液中,将带有谷部被倒角了的凹凸部的n型单晶硅基板1浸渍5~60秒。在蚀刻中,也可以搅拌蚀刻溶液。由此,蚀刻的进展变得均匀。

[0068] 像这样,在形成了在谷部具有平坦部F的凹凸部P之后,如图6-1所示,在n型单晶硅基板1的单面,使用化学气相生长(CVD)法,依次形成i型非晶硅层2a、p型非晶硅层3。i型非晶硅层2a、p型非晶硅层3各自的膜厚是5nm。在本实施方式中,将膜厚设为5nm,但根据层的形成条件,也可以是3nm以上且10nm以下的范围的膜厚。作为CVD,优选使用等离子体CVD、热CVD法等。为了针对作为光电变换层的n型单晶硅基板1产生充分的内置电场,p型非晶硅层3的带隙、活性化能量分别需要1.7eV以上、0.4eV以下。另外,也可以代替i型非晶硅层2a,而使用i型非晶质碳化硅层、i型非晶质氧化硅层或者层叠了它们的多层膜。另外,也可以代替p型非晶硅层4而使用p型非晶质碳化硅层、p型非晶质氧化硅层、p型微晶硅层或者层叠了它们的多层膜等。

[0069] 由此,由(111)面构成了70~85°的陡峭的截面V字状的槽的凹凸部P的底部通过构成平坦部F而能够广角化为115~135°。因此,相比于使槽的底部倒角了的基板,能够将(100)面降低10~20%。

[0070] 这样,在n型单晶硅基板1的单面形成了i型非晶硅层2a、p型非晶硅层3之后,如图6-2所示,在n型单晶硅基板1的受光面的相反侧,使用化学气相生长(CVD)法,依次形成i型非晶硅层2b、n型非晶硅层4。i型非晶硅层2b、n型非晶硅层4各自的膜厚是5nm。在本实施方式中,将膜厚设为5nm,但根据层的形成条件,也可以是3nm以上且20nm以下的范围的膜厚。作为CVD,优选使用等离子体CVD、热CVD法等。为了针对作为光电变换层的n型单晶硅基板1产生充分的内置电场,n型非晶硅层4的带隙、活化能量分别需要1.7eV以上、0.3eV以下。另外,也可以代替i型非晶硅层2b而使用i型非晶质碳化硅层、i型非晶质氧化硅层或者将它们层叠而成的多层膜。另外,也可以代替n型非晶硅层4而使用n型非晶质碳化硅层、n型非晶质氧化硅层、n型微晶硅层或者将它们层叠而成的多层膜等。

[0071] 也可以在n型单晶硅基板1的单面形成了i型非晶硅层2b、n型非晶硅层4之后,为了降低i型非晶硅层和n型单晶硅基板1的界面缺陷,在惰性气体或者用惰性气体稀释了的氢气中,实施热退火处理。期望退火温度为200℃以下。

[0072] 在热退火处理之后,如图 6-3 所示,在 p 型非晶硅层 3、n 型非晶硅层 4 上,用溅射法或者蒸镀法形成透光性电极 5a、5b。关于透光性电极 5a、5b 的膜厚,根据降低反射率的观点,期望为约 70nm。作为透光性电极材料,使用氧化铟锡 (ITO:Indium Tin Oxide)、或者氧化铟 ( $\text{In}_2\text{O}_3$ :Indium Oxide) 等透光性导电膜 (TCO:Transparent Conductive Oxide)。另外,期望透光性电极 5a、5b 的电阻率低,但如果承担导电性的载流子密度高,则光吸收率会增加。因此,用作透光性电极 5a、5b 的材料必须是高移动度。为了以 70nm 的膜厚达到充分低的电阻率,期望移动度为  $100\text{cm}^2/\text{Vs}$  以上。另外,作为下层侧的透光性电极材料,也可以使用添加了铝 (Al)、镓 (Ga) 等的氧化锌 ( $\text{ZnO}$ :Zinc Oxide)。

[0073] 在 n 型非晶硅层 4 上形成了透光性电极 5b 之后,如图 6-4 所示,在透光性电极 5b 上用溅射法或者蒸镀法形成由 Ag 构成的背面电极 7。背面电极 7 的膜厚是约 300nm,作为材料使用 Ag。也可以不是形成背面电极 7,而是在透光性电极 5b 上用丝网印刷法或者电镀法等形成由 Ag 构成的集电极。关于背面电极 7 的材料,期望具有高反射率以及导电性,也可以代替 Ag 而使用铝 (Al)、金 (Au)、铜 (Cu) 等。

[0074] 在 p 型非晶硅层 3 上形成了透光性电极 5a 之后,如图 6-5 所示,在透光性电极 5a 上用丝网印刷法形成由 Ag 构成的集电极 6。另外,关于构成集电极 6 的栅格电极 (grid electrode) 的宽度,为了抑制遮光,越窄越好,但电阻会增加。因此,关于栅格电极,期望宽度窄,且膜厚大。在本实施方式中,将宽度设为  $50\mu\text{m}$ ,将膜厚设为  $60\mu\text{m}$ 。另外,除了丝网印刷以外,还可以用电镀法等来形成集电极 6。在印刷了集电极 6 之后,在  $200^\circ\text{C}$  以下进行烧制。关于这样形成的晶体系硅太阳能电池的凹凸构造的谷部形状,通过 TEM 观察确认到:从图 8 所示的比较例 1 的晶体系硅太阳能电池 Ref-I 以及图 9 所示的比较例 2 的晶体系硅太阳能电池 Ref-II 的形状,变成具有图 3 所示那样的平坦部 F 的形状。

[0075] 接下来,表 1 示出准备根据上述方法制造的晶体系硅太阳能电池、比较例 1 的晶体系硅太阳能电池 Ref-I 和比较例 2 的晶体系硅太阳能电池 Ref-II,测定太阳能电池特性的结果,其中比较例 1 的晶体系硅太阳能电池 Ref-I 是在 n 型单晶硅基板 1 仅形成金字塔状的凹凸且按照与本实施方式的太阳能电池相同的条件制作的,比较例 2 的晶体系硅太阳能电池 Ref-II 是在 n 型单晶硅基板 1 形成谷部被倒角了的凹凸部 P 且按照与本发明相同的条件制作的。

[0076] [表 1]

[0077]

|                                  | <b>Jsc</b><br>( $\text{mA}/\text{cm}^2$ ) | <b>Voc</b><br>(V) | <b>F.F.</b><br>(-) | <b><math>\eta</math></b><br>(%) |
|----------------------------------|-------------------------------------------|-------------------|--------------------|---------------------------------|
| <b>本实施方式</b>                     | <b>37.3</b>                               | <b>0.708</b>      | <b>0.780</b>       | <b>20.6</b>                     |
| <b>比较例 1</b><br><b>Ref-I 形状</b>  | <b>37.5</b>                               | <b>0.658</b>      | <b>0.761</b>       | <b>18.8</b>                     |
| <b>比较例 2</b><br><b>Ref-II 形状</b> | <b>37.3</b>                               | <b>0.681</b>      | <b>0.769</b>       | <b>19.5</b>                     |

[0078] 根据表 1 也可知,本实施方式的晶体系硅太阳能电池相比于比较例 1 的晶体系硅太阳能电池 Ref-I,开路电压 (Voc) 以及曲线因子 (F.F.) 增加与谷部形状变化相伴的短路电流 Jsc 的减少量以上,能够提高变换效率  $\xi$  (%)。由于平坦部长度越长,反射率越增加, Jsc 越减少,所以基于平坦部形成的 Voc 和 F.F. 与 Jsc 处于折衷的关系。另外,可知关于本实施方式的晶体系硅太阳能电池的特性,即使与比较例 2 的晶体系硅太阳能电池 Ref-II 的情况比较,开路电压 (Voc) 以及曲线因子 (F.F.) 的增加量也大,变换效率提高效果也大。F.F. 是曲线因子 (fill factor), 且是表示最大输出相对理论输出的比例的数值,成为太阳能电池模块的品质的目标之一。理论输出相当于开路电压以及短路电流之积。关于 F.F., 在最大输出与理论输出相同的情况下设为最大值 1, 数值越接近 1 表示发电效率越高。

[0079] 图 10-1 是示出在谷部具有倒角的 n 型单晶硅基板和本发明中的在谷部具有平坦部 F 的 n 型单晶硅系基板 1 的归一化反射率、以及用该 n 型单晶硅基板 1 制作的晶体系硅太阳能电池的归一化 Voc 的关系的曲线图。以未对纹理谷部实施追加加工的比较例 1 的晶体系硅太阳能电池 Ref-I 的反射率以及 Voc 为基准,进行了归一化。曲线 a 表示本实施方式 1 的 n 型单晶硅基板 1、即对纹理谷部实施追加加工而形成了平坦部 F 的基板, 曲线 b 表示对纹理谷部实施了倒角加工的比较例 2 的晶体系硅太阳能电池 Ref-II 的基板。根据该曲线图能够确认,本实施方式的晶体系硅太阳能电池相比于比较例 2 的晶体系硅太阳能电池 Ref-II, Voc 提高。这被认为是由于在本实施方式的晶体系硅太阳能电池中,通过使凹部角度广角化,能够抑制陡峭的谷部形状所引起的钝化膜的缺陷以及外延生长。根据反复进行实验的结果可知,在具有相同程度的反射率时,本实施方式的晶体系硅太阳能电池的 n 型单晶硅基板 1 相比于对槽的底部附加了倒角的比较例 2 的晶体系硅太阳能电池 Ref-II 的基板,能够将 (100) 面降低 10 ~ 20%。因此,根据本实施方式的晶体系硅太阳能电池,能够抑制 (100) 面所引起的非品质膜中的外延生长以及缺陷的产生,能够实现光电变换效率的提高。

[0080] 进而,如果比较具有相同程度的反射率的比较例 2 的晶体系硅太阳能电池 Ref-II 的形状和本实施方式的晶体系硅太阳能电池,则可知本实施方式的晶体系硅太阳能电池相比于比较例 2 的晶体系硅太阳能电池 Ref-II, Voc 的增加量更大。这被认为是由于在谷部具有平坦部 F 的形状相比于在谷部具有倒角的形状,伴随谷部的形状加工而产生的 (100) 面以及近 (100) 面区域更小,并且与倒角形状相伴的原子台阶状的形状变化消失。根据截面 TEM 像,求出谷部中的 (100) 面以及近 (100) 面的一维区域的结果,在呈现相同程度的反射率的基板中,关于 (100) 面以及近 (100) 面的一维区域,本实施方式的太阳能电池相比于比较例 2 的晶体系硅太阳能电池 Ref-II 少 10 ~ 20% 左右。另外,比较例 2 的晶体系硅太阳能电池 Ref-II 中的基板的谷部形状存在与倒角形状相伴的原子台阶状的变化,相对于此,本实施方式的太阳能电池中的基板的谷部形状由大致 (111) 面和大致 (100) 面构成。因此,本实施方式的太阳能电池能够抑制在比较例 2 的晶体系硅太阳能电池 Ref-II 中可见到那样的原子台阶状的构造变化所引起的、钝化膜的缺陷以及外延生长。

[0081] 根据以上,可以认为本实施方式 1 的具有谷部构造的 n 型单晶硅基板 1 相比于比较例 2 的晶体系硅太阳能电池 Ref-II,能够进一步抑制非晶硅层的缺陷和外延生长。

[0082] 图 10-2 是示出谷部的平坦部 F 的长度与 Voc 的关系的曲线图。曲线 a 表示本实施方式 1 的 n 型单晶硅基板 1 中的平坦部 F 的长度与 Voc 的关系。根据该图可知,本实施

方式 1 的晶体系硅太阳能电池在平坦部长度是 600nm 以下时具有提高  $V_{oc}$  的效果。可知如果平坦部 F 的长度过长,则 n 型单晶硅基板 1 的反射率增加而短路电流  $J_{sc}$  大幅减少,同时在钝化膜中会大量地产生由 (100) 面所引起的缺陷以及外延生长,得不到充分的效果。如果考虑图 10-2 以及  $J_{sc}$  的降低量,则能够判断为更适合的平坦部 F 的长度是 500nm 以下。另外,通过之后的追加实验,确认到在平坦部(平台部)长度是约 50nm 时,归一化反射率以及归一化  $V_{oc}$  分别是 1.011、1.009,在平坦部长度是 50nm 时,也具有提高  $V_{oc}$  的效果。

[0083] 像这样,在本实施方式的异质结型的太阳能电池中,由于使用了形成金字塔构造且在谷部具有平坦部 F 的 n 型单晶硅基板 1,所以能够使由大致 (111) 面形成的陡峭的凹部角度广角化,所以能够消除倒角形状所引起的原子台阶状的形状变化,并且,相比于对反射率同等的谷部附加了倒角的基板,能够将 (100) 面以及近 (100) 面的区域在一维上降低 10 ~ 20%。因此,能够抑制陡峭的纹理形状或者倒角形状以及由 (100) 面所引起的非晶质膜中的外延生长以及缺陷。因此,形成表面的光反射率低并且缺陷少的半导体膜。因此,能够将开路电压  $V_{oc}$  以及 F.F. 提高与形状变化相伴的短路电流  $J_{sc}$  的减少量以上,所以能够提高晶体系硅太阳能电池的输出特性,实现光电变换效率高的太阳能电池。

[0084] 实施方式 2.

[0085] 图 11-1 ~ 图 11-3 是示出使用了具有该纹理构造的 p 型单晶硅基板 1p 的本发明的实施方式 2 的晶体系硅太阳能电池的制造工序的工序截面图。另外,在所述实施方式 1 中,对在具有纹理构造的基板表面通过 CVD 法形成由非晶质薄膜构成的 i 型非晶硅层 2a、p 型非晶硅层 3 的薄膜型的太阳能电池进行了说明,但本实施方式应用于在 p 型单晶硅基板 1p 中通过扩散形成 n 型硅扩散层并形成了 pn 结的情况的接合型的太阳能电池。不同点在于:代替在所述实施方式 1 中与 n 型单晶硅基板形成 pn 结的 p 型非晶硅层,在本实施方式中,在 p 型单晶硅基板 1p 表面,通过扩散形成了 n 型硅扩散层 3d。另一方面,在背面侧,通过由铝层等构成的背面侧电极 17 的烧制时的扩散,形成了 p 型硅扩散层 (BSF 层) 15。关于背面,在高温下烧制背面侧电极 17 时,硅和铝熔融、纹理消失而成为平台(平坦)形状,但原本在两面都形成纹理。

[0086] 在形成了与实施方式 1 同样的金字塔构造或者逆金字塔构造的 p 型单晶硅基板 1p 等第一导电类型的晶体系的硅基板的受光面侧,首先,通过扩散形成 n 型硅扩散层 3d,形成 pn 结(图 11-1)。例如,将上述纹理形成处理完成了的 p 型单晶硅基板 1p 投入到热扩散炉,在三氯氧磷 ( $POCl_3$ ) 蒸气的存在下加热而在 p 型单晶硅基板 1p 的表面形成磷玻璃并在 p 型单晶硅基板 1p 使磷扩散,作为第二导电类型层,形成 n 型硅扩散层 3d,形成 pn 结。另外,由于此处使用了 p 型的硅基板,所以为了形成 pn 结而使不同的导电类型的磷扩散,但在使用了 n 型硅基板时,使 p 型的杂质扩散即可。该扩散法有气相扩散、固相扩散、涂布扩散等,例如,通过组合使用喷墨法而在硅基板表面形成扩散源的工序、和使扩散源通过退火来向硅基板的内部扩散的工序而形成。

[0087] 接下来,在氢氟酸溶液中去掉 p 型单晶硅基板 1p 的磷玻璃层,在去除了在 p 型单晶硅基板 1p 的受光面侧的面以外形成的第二导电类型层之后 (pn 分离),通过例如 CVD 法等,在 p 型单晶硅基板 1p 的受光面侧,形成具有钝化效果和反射防止效果的电介质膜 8(图 11-2)。作为具有钝化效果和反射防止效果的电介质膜 8 的材料,可以举出  $SiN(Si_3N_4)$ 、或者  $SiO_2$  或  $Al_2O_3$  中的某一个、或者包含一个的材料。关于电介质膜 8 的膜厚以及折射率,考

虑到使抑制光反射的值、或者终止表面缺陷的值而设定为同时实现的最佳的值。另外,也可以沉积折射率不同的层。另外,电介质膜 8 也可以通过溅射法等不同的成膜方法来形成。

[0088] 接下来,使用丝网印刷法等在 p 型单晶硅基板 1p 的受光面梳状地印刷含有银的膏来形成受光面侧电极 16,在背面侧整个面地印刷含有铝的膏来形成背面电极 17。之后,实施 800℃ 的烧制工艺。通过该烧制工艺,在受光面侧,贯通电介质膜 8,受光面侧电极 16 与 n 型硅扩散层 3d 接触。另一方面,在背面侧,背面电极 17 的铝等金属扩散到 p 型单晶硅基板 1p 而形成 p 型硅扩散层 (BSF 层) 15,得到扩散接合型的太阳能电池 (图 11-3)。

[0089] 关于本实施方式 2 的太阳能电池,作为结构,不同点在于:代替在实施方式 1 的太阳能电池中通过利用 CVD 法等成膜而形成的非晶质薄膜,通过杂质扩散来形成具有期望的杂质浓度的半导体层 (硅层)。

[0090] 以往,即使在具有纹理构造的半导体基板表面形成扩散层的情况下,在金字塔状的凹凸部的谷部中,在基板受光面制成的钝化膜中由于杂质的集中,也易于产生缺陷,无法得到充分的光电变换效率。相对于此,根据本实施方式,通过在金字塔型的凹凸部 P 的谷部的底部形成平坦部 F,能够抑制在谷部中产生缺陷,能够实现光电变换效率的提高。

[0091] 另外,在所述实施方式中,使用了形成为金字塔状的凹凸部 P 的谷部具有平坦部 F 的单晶硅基板,但即使在具有逆金字塔状的凹部的纹理构造中,也通过形成为谷部具有平坦部 F,能够与所述实施方式 1 的情况同样地,形成缺陷少的电介质膜 8。这是由于:伴随谷部的形状加工而产生的 (100) 面或者近 (100) 面区域变小,并且与倒角相伴的原子台阶状的形状的形状变化消失,即使在该表面通过扩散形成 pn 结并在其上形成电介质膜 8 的情况下,也能够形成结晶性高的膜。清楚的是:该电介质膜 8 由于与硅基板的折射率的差异而具有作为反射防止膜的功能,并且起到防止在 pn 结部中生成的载流子的复合的极其重要的作用,可知通过提高该电介质膜 8 的膜质,对太阳能电池的光电变换效率提高起到极其重要的作用。

[0092] 另外,本实施方式不仅能够应用于在 p 型硅基板通过扩散来形成 n 型硅扩散层并形成了 pn 结的情况下的接合型的太阳能电池,而且当然还能够应用于在 n 型硅基板中通过扩散来形成 p 型硅扩散层并形成了 pn 结的接合型的太阳能电池。

[0093] 实施方式 3.

[0094] 图 12-1、图 12-2 是示出作为构成本发明的太阳能电池的实施方式 3 的晶体系硅太阳能电池的晶体系硅基板的、n 型单晶硅基板 1 的截面影像图、以及平面影像图的图。图 12-1 是图 12-2 的 A-A 截面图。在该硅太阳能电池中,与所述实施方式 1 同样地,作为晶体系的硅基板,使用了电阻率是  $1 \sim 10 \Omega \cdot \text{cm}$ 、主表面由 (100) 面构成、厚度是  $50 \mu\text{m}$  以上且  $300 \mu\text{m}$  以下的 n 型单晶硅基板 1。在该 n 型单晶硅基板 1 的表面,规则地排列了多个谷部的顶点构成平坦部 F 的逆金字塔状的凹凸部 P。该凹凸部 P 成为在 4 根棱线形成的谷部具有平坦部 F 的逆金字塔状、在逆金字塔形状的底面具有大致正方形的平坦部 F 的结构。S 表示逆金字塔状的凹部的侧面。

[0095] 另外,作为太阳能电池的构造,表面的纹理形状不同,除此以外,与实施方式 1 的太阳能电池相同,所以此处省略说明。

[0096] 如图 12-1 以及图 12-2 所示,在以规则地排列的逆四角锥状 (逆金字塔状) 的凹部为基本的纹理构造的凹凸部 P 的谷部的底部,形成与 4 根棱线连接的平坦部 F,换言之,在

纹理的谷部具有大致正方形的平坦部 F。

[0097] 接下来,说明本发明的实施方式 3 的晶体硅太阳能电池的制造方法。图 13 是说明本发明的实施方式 3 的晶体硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的流程图。图 14-1 ~ 图 14-6 是说明本发明的实施方式 3 的晶体硅太阳能电池的制造方法中的用于形成具有纹理构造的 n 型单晶硅基板的纹理形成工序的步骤的截面图。关于使用了具有该纹理构造的 n 型单晶硅基板的晶体硅太阳能电池的制造工序,与在前述实施方式 1 中使用图 6-1 ~ 图 6-5 的工序截面图说明的部分相同,所以此处省略说明。

[0098] 在本实施方式的太阳能电池的制造方法中,形成纹理构造的工序包括:在硅基板的表面形成抗蚀刻膜(步骤 S10),在该抗蚀刻膜中使用光刻或者激光加工来形成开口部而形成具有以一定间隔规则地排列了的开口部的抗蚀刻膜(步骤 S20)的工序;第一工序(步骤 S30),将抗蚀刻膜作为掩模,实施各向异性蚀刻,在所述开口部的下部及其附近区域形成多个逆金字塔型的凹凸部 P;第二工序(步骤 S40),实施各向同性蚀刻,对逆金字塔型的凹凸部 P 的角部附加倒角;以及第三工序(步骤 S50),实施各向异性蚀刻,在所述金字塔型的凹凸部 P 的谷部形成平坦部 F。

[0099] 首先,作为基板,准备主面的晶面取向为(100)的 n 型单晶硅基板 1(图 14-1)。n 型单晶硅基板 1 是从掺杂成期望的浓度的 n 型的单晶硅锭用多线锯切片而得到的。

[0100] 接下来,在 n 型单晶硅基板 1 的成为受光面侧的表面及其相向面即背面,形成逆金字塔型的纹理形成时的成为蚀刻掩模的抗蚀刻膜 R(步骤 S10、图 14-2)。图 14-2 示出在具有晶面取向(100)的 n 型单晶硅基板 1 的成为受光面侧的表面以及背面形成抗蚀刻膜 R 的状态。

[0101] 关于用作蚀刻掩模的抗蚀刻膜 R 的材料,除了由高分子材料构成的感光性树脂等由有机材料构成的有机抗蚀剂以外,还使用由无机材料构成的无机抗蚀剂。特别是,作为本实施方式中的抗蚀刻膜 R 的材料,优选为无机材料,能够使用例如硅氧化膜或者硅氮化膜。作为抗蚀刻膜 R 的成膜方法,优选选择对 n 型单晶硅基板 1 的损伤少的方法,除了常压 CVD(Chemical Vapor Deposition,化学气相沉积)法、LPCVD(Low Pressure Chemical Vapor Deposition,低压化学气相沉积)法、PECVD(Plasma-Enhanced Chemical Vapor Deposition,等离子体增强化学气相沉积)法以外,还能够使用 ALD(Atomic Layer Deposition;原子层沉积)等方法。在本实施方式中,对作为抗蚀刻膜 R 使用由无机材料构成的无机抗蚀剂的情况进行说明。

[0102] 接下来,在抗蚀刻膜 R 形成作为蚀刻用的开口使用的、以一定间隔纵横规则地排列的多个开口部 O 来形成蚀刻掩模(步骤 S20、图 14-3)。开口部 O 在 n 型单晶硅基板 1 的面方向上以矩阵状被配置。

[0103] 作为形成开口部 O 的方法,在对抗蚀刻膜 R 使用了高分子材料的情况下,使用光刻法等化学性的方法。另一方面,在对抗蚀刻膜 R 使用了无机材料的情况下,使用激光等物理性的手法直接进行描绘,或者在使用光刻形成了有机系抗蚀剂的图案之后,将其作为掩模进行蚀刻,从而能够进行图案形成。关于抗蚀刻膜 R 的加工用的激光器,优选不透过硅的激光器,使用例如 Nd:YAG 激光器的二次谐波即波长 532nm 的激光器即可。另外,在通过激光加工抗蚀刻膜 R 的情况下,作为抗蚀刻膜 R,优选使用在膜中含有氢的材料。

[0104] 如上述那样在由无机材料构成的抗蚀刻膜 R 通过激光加工形成开口部 O, 并从该开口部 O 对 n 型单晶硅基板 1 实施蚀刻的方法, 其生产性优良, 优点多。使用光刻法来形成蚀刻掩模的方法比激光加工在精度这点上更优良。然而, 在利用各向异性蚀刻的 n 型单晶硅基板 1 表面的加工中, 即使开口部 O 的形状有偏差, 对于光反射率的影响也轻微, 不成为激光加工的缺点。反倒, 即使在 n 型单晶硅基板 1 自身未完全研磨为平坦、而具有切片加工所致的凹凸的情况下, 也能够无问题地形成蚀刻掩模, 能够得到同样的效果。

[0105] 该开口部 O 被形成在抗蚀刻膜 R 的面方向上残留规则性的岛状的图案。即, 抗蚀刻膜 R 是将与通过蚀刻在 n 型单晶硅基板 1 中形成的逆金字塔型的凹凸部 P 的形状对应的正方形区域作为单位形成区域, 在抗蚀刻膜 R 的面方向上矩阵状地形成的。相对 n 型单晶硅基板 1 的 (100) 面, 在  $\langle 010 \rangle$  轴方向以及  $\langle 001 \rangle$  轴方向上, 排列了图 14-3 所示的各个开口部 O。关于该形状, 在使 n 型单晶硅基板 1 的 (111) 面的蚀刻进展时, 从与 (100) 面垂直的方向观察时, 处于被蚀刻而露出的 (111) 面彼此与交叉的棱线重叠的方向。

[0106] 接下来, 将该抗蚀刻膜 R 作为掩模, 对 n 型单晶硅基板 1 的受光面侧的表面, 经由开口部 O, 实施各向异性蚀刻。在该各向异性蚀刻中, 将例如 n 型单晶硅基板 1 浸渍到碱性溶液, 从抗蚀刻膜 R 的开口部 O 向 n 型单晶硅基板 1 的表面供给碱性溶液。作为碱性溶液, 使用例如氢氧化钠 (NaOH) 水溶液、氢氧化钾 (KOH) 水溶液等。这些水溶液的浓度优选为 3 重量%以上且 10 重量%以下, 也可以添加例如异丙醇 (IPA) 等有机物、界面活性剂等。另外, 蚀刻时的这些水溶液的温度优选设为  $70^{\circ}\text{C}$  以上且  $90^{\circ}\text{C}$  以下。蚀刻时间优选为 20 ~ 40 分钟。另外, 如果能对 n 型单晶硅基板 1 的受光面侧的表面经由开口部 O 实施各向异性蚀刻, 则也可以不必将 n 型单晶硅基板 1 浸渍到碱性溶液。

[0107] 如果通过碱性水溶液对 n 型单晶硅基板 1 的表面进行各向异性蚀刻, 则在蚀刻的速度快的 (100) 面等中蚀刻进展, 如果形成仅由蚀刻的速度极其慢的 (111) 面构成的凹凸部 P, 则蚀刻的进展变慢。然后, 如果使用具有在  $\langle 010 \rangle$  轴方向以及  $\langle 001 \rangle$  轴方向上矩阵状地排列了的开口部 O 的蚀刻掩模来进行该各向异性蚀刻, 则逆金字塔型的凹凸部 P 形成于开口部 O 的下部 (步骤 S30、图 14-4)。图 14-4 示出形成了具有晶面取向为 (111) 的斜面的逆金字塔型的凹凸部 P 的状态。

[0108] 该逆金字塔型的凹凸部 P 具有晶面取向为 (111) 的斜面。逆金字塔型的凹凸部 P 是在将 n 型单晶硅基板 1 的受光面设为上侧时形成四角锥形状的凹部的结构, 俯视时呈现正方形形状, 还被称为逆金字塔型构造。各逆金字塔型的凹凸部 P 是 4 个斜面交叉而形成的, 其底部形成凹部形状的最深部 E。

[0109] 这样, 如图 14-4 所示, 进行表面加工, 以使得在 n 型单晶硅基板 1 的表面具有由被称为纹理的大致 (111) 面形成的逆金字塔状的凹凸部 P。也可以在形成抗蚀刻膜 R 之前, 为了抑制蚀刻不均, 实施基板的收纳清洗。进而, 也可以实施去除基板表面的损伤层的工序。另外, 在损伤层去除工序之后, 期望为了提高性能而实施基板内杂质的吸气处理。作为吸气处理, 使用磷扩散处理等。

[0110] 接下来, 如图 14-5 (步骤 S40) 所示, 对形成有凹凸部 P 的 n 型单晶硅基板 1 实施各向同性蚀刻, 在谷部形成倒角。平面影像图与图 12-2 相同。作为各向同性蚀刻溶液, 能够使用氢氟酸 (HF) 和硝酸 ( $\text{HNO}_3$ ) 的混合液、或者氢氟酸 (HF)、硝酸 ( $\text{HNO}_3$ ) 以及醋酸 ( $\text{CH}_3\text{COOH}$ ) 的混合液等。由于通过调整浓度或者处理时间, 能够控制谷部倒角形状, 所以对浓度或者处

理时间的条件不作限定。在将例如氢氟酸 (HF) 和硝酸 (HNO<sub>3</sub>) 以 1:10 ~ 1:100 的比例混合了的水溶液中,将形成有所述凹凸部 P 的 n 型单晶硅基板 1 浸渍 10 秒 ~ 5 分钟为好。在蚀刻中,也可以搅拌蚀刻溶液。通过该蚀刻,抗蚀刻膜也被去除。另外,各向同性蚀刻不限于湿法蚀刻,还能够通过干法蚀刻进行。

[0111] 进而,对形成有所述谷部被倒角了的凹凸部 P 的 n 型单晶硅基板 1,实施短时间的各向异性蚀刻处理,在谷部形成平坦部 F (步骤 S50)。得到如图 14-6 所示形成有在谷部具有平坦部 F 的逆金字塔状的凹凸部 P 的 n 型单晶硅基板 1。

[0112] 像这样,成为在谷部具有平坦部 F 的逆金字塔状的凹部被规则地排列而成的凹凸部 P。像这样在形成了凹凸部 P 之后,与实施方式 1 同样地,在 n 型单晶硅基板 1 的单面依次形成 i 型非晶硅层 2a、p 型非晶硅层 3,形成 pn 结而形成太阳能电池。

[0113] 由此,即使在本实施方式的太阳能电池中,由 (111) 面构成了 70 ~ 85° 的陡峭的截面 V 字状的槽的凹凸部 P 的底部通过构成平坦部 F 而广角化为 115 ~ 135°。因此,相比于使槽的底部倒角了的基板,能够将 (100) 面降低 10 ~ 20%。

[0114] 另外,在所述实施方式 1 ~ 3 中,对单晶硅基板进行了说明,但不限于单晶硅基板,还能够应用于使用了多晶硅基板的情况。在使用了多晶硅基板的情况下,金字塔部的形状变得随机,同样地存在如下的问题:产生与谷部倒角相伴的谷部中的原子台阶状的形状变化,在基板上层叠的非晶硅层中易于产生缺陷,但通过应用本发明,能够避免这样的缺陷,能够提供光电变换效率高的太阳能电池。

[0115] 另外,通过形成多个由具有在所述实施方式 1 ~ 3 中说明了的结构的太阳能电池构成的单元,并将邻接的太阳能电池单元彼此串联或者并联地电连接,能够提供具有良好的陷光效应,光电变换效率优良的太阳能电池模块。在该情况下,将例如邻接的太阳能电池单元的受光面侧的电极层和另一方的背面侧的电极层电连接即可。

[0116] 产业上的可利用性

[0117] 如以上那样,本发明的太阳能电池及其制造方法对实现具有金字塔型的纹理构造而具有低光反射率以及高光电变换效率的太阳能电池是有用的。

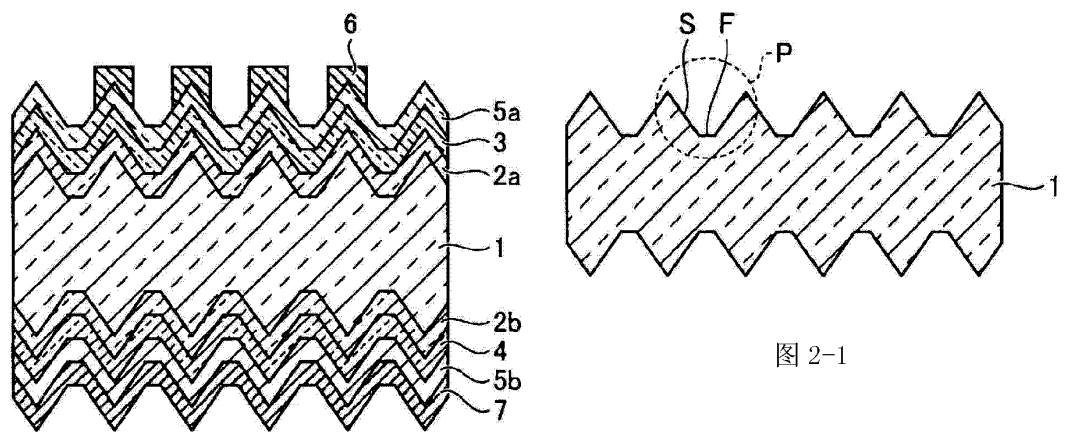


图 2-1

图 1

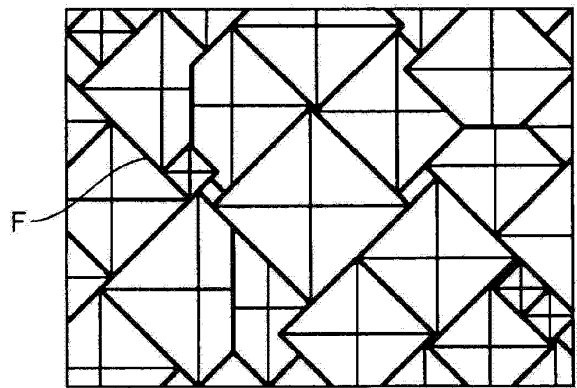


图 2-2

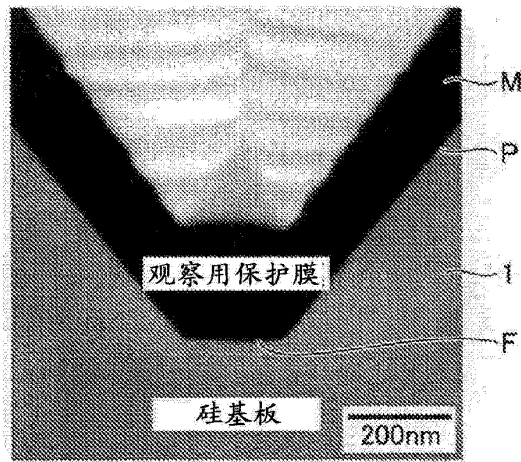


图 3

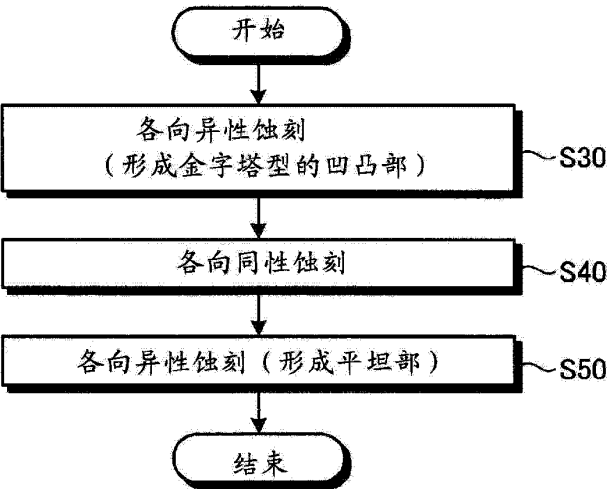


图 4

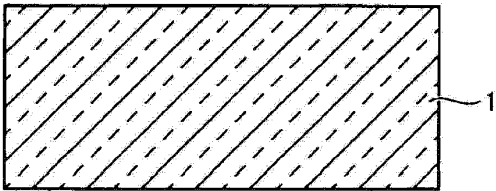


图 5-1

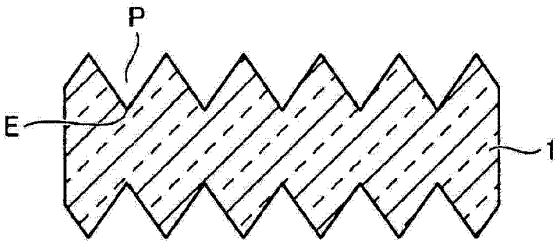


图 5-2

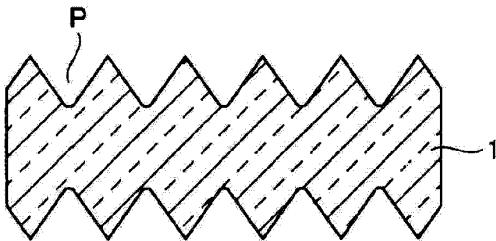


图 5-3

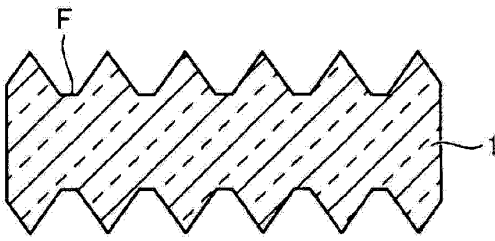


图 5-4

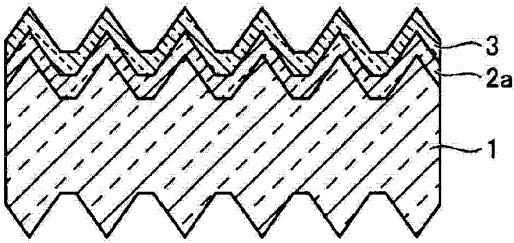


图 6-1

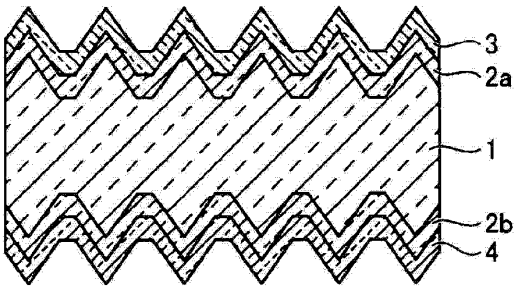


图 6-2

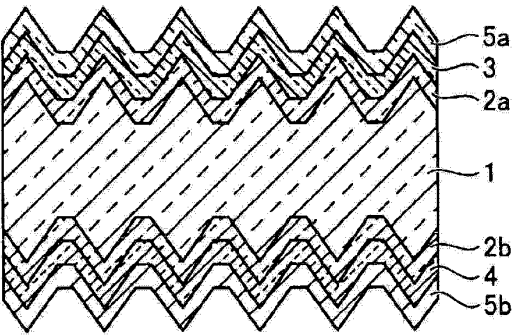


图 6-3

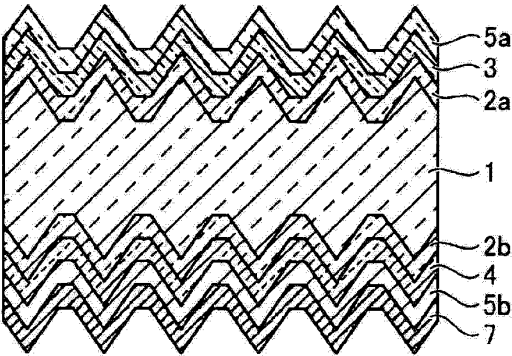


图 6-4

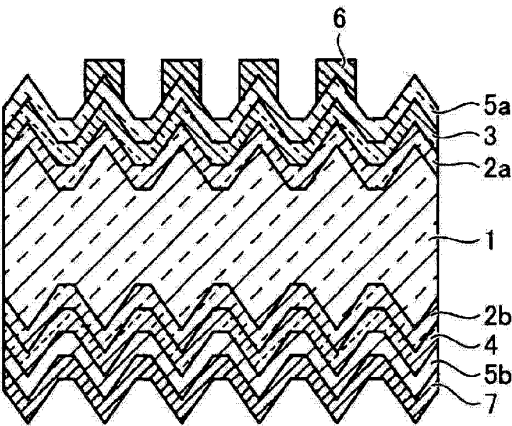


图 6-5

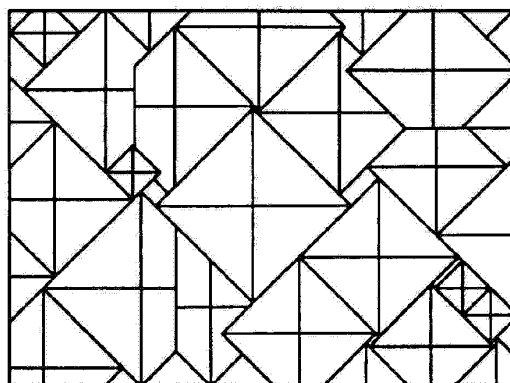


图 7

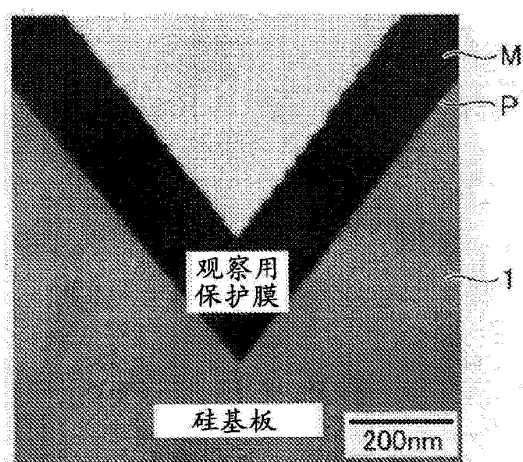


图 8

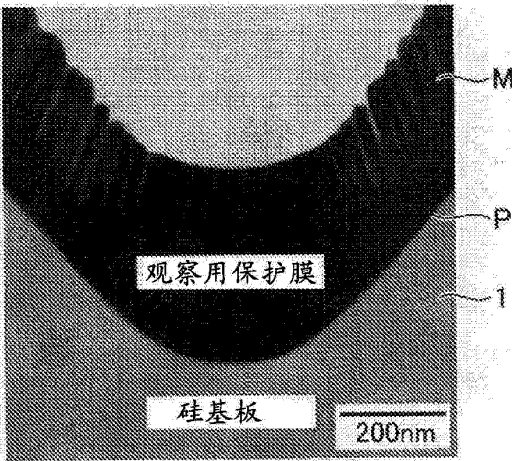


图 9

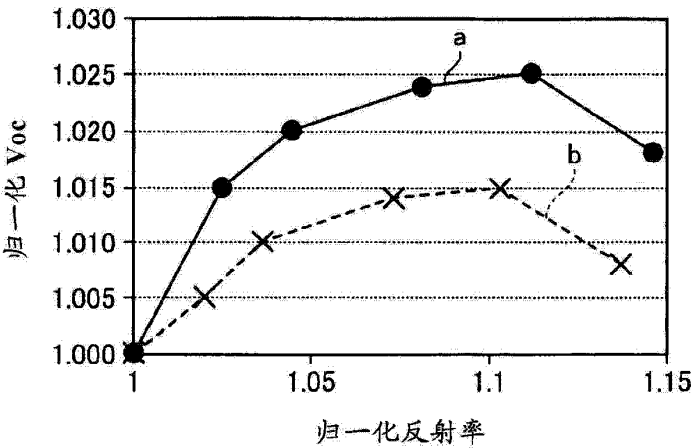


图 10-1

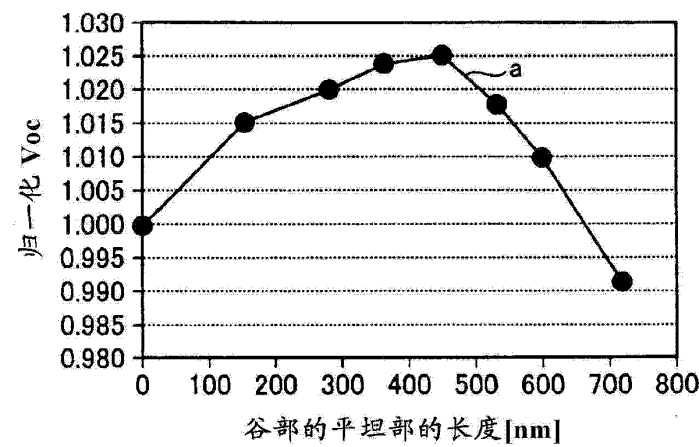


图 10-2

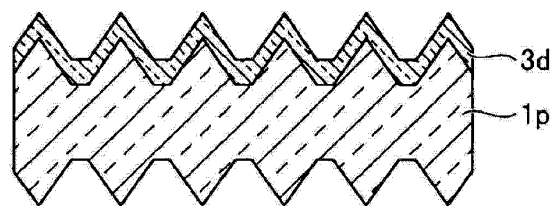


图 11-1

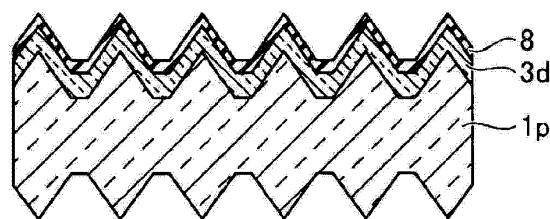


图 11-2

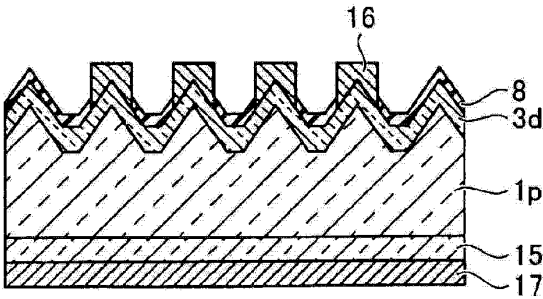


图 11-3

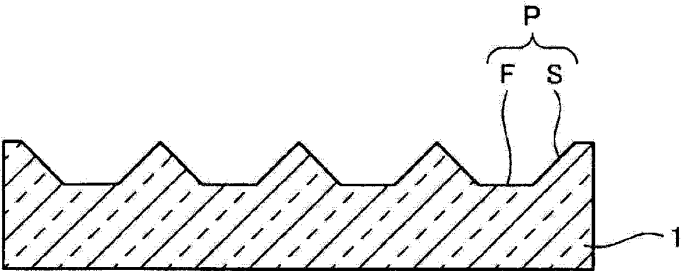


图 12-1

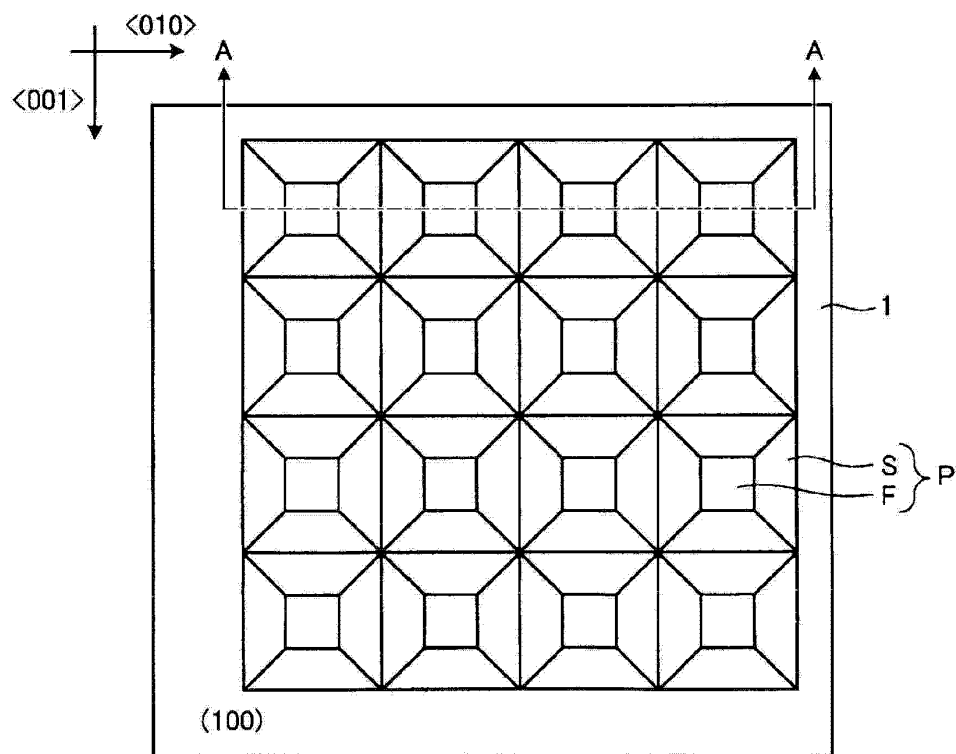


图 12-2

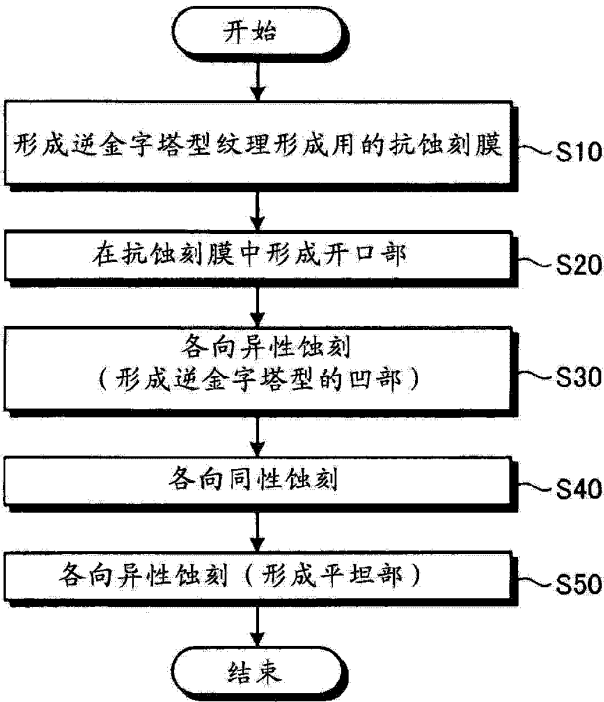


图 13

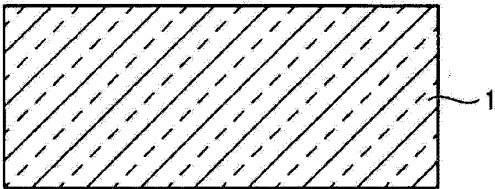


图 14-1

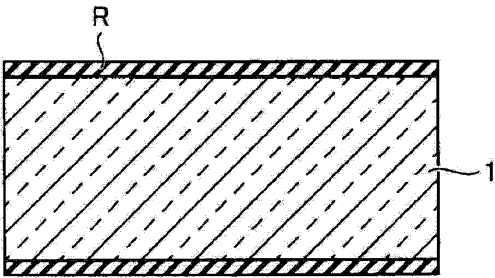


图 14-2

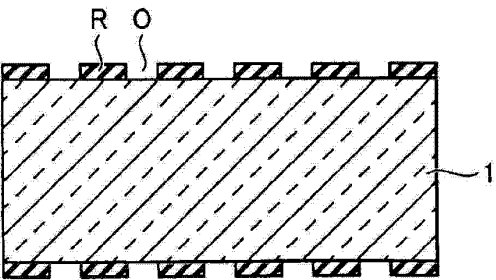


图 14-3

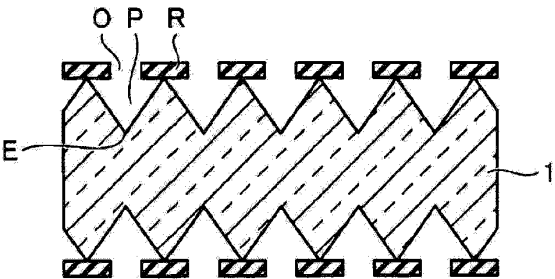


图 14-4

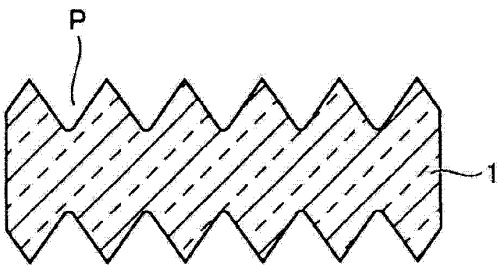


图 14-5

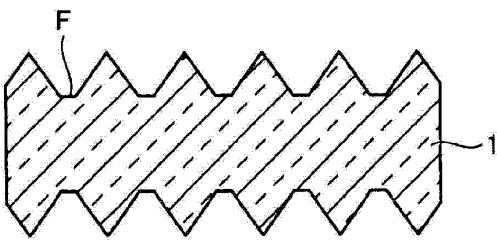


图 14-6



Espacenet

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Mono-crystalline silicon double-sided solar cell and preparation method thereof

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H01L31/18  
- **cooperative:** H01L31/02168 (CN); H01L31/0236 (EP);  
H01L31/02363 (CN); H01L31/068 (CN);  
H01L31/1804 (CN); Y02E10/547 (EP); Y02P70/50 (EP)

**Application number:** CN201610331351 20160517 Global Dossier**Priority number(s):** CN201610331351 20160517**Also published as:** WO2017197811 (A1)

Abstract of CN105826405 (A)

The invention discloses a mono-crystalline silicon double-sided solar cell, and belongs to the technical field of solar cells. A front pyramid-shaped texture surface, a front doped emitter junction, a front passivated anti-reflection medium layer and a front electrode are sequentially formed on the front of a mono-crystalline silicon substrate. A back pyramid-shaped texture surface, a back surface field, a back passivated anti-reflection medium layer and a back electrode are sequentially formed on the back of the mono-crystalline silicon substrate. The mono-crystalline silicon double-sided solar cell is characterized in that the back pyramid-shaped texture surface is a separated pyramid-shaped texture surface, the pyramid structure partially covers the mono-crystalline silicon substrate and is dispersedly distributed on the silicon substrate, and the area covered by the pyramid structure accounts for 20-90% of the back silicon substrate. The invention further discloses a preparation method of the mono-crystalline silicon double-sided solar cell. The minority carrier surface recombination and optical absorption characteristics of the double-sided solar cell are optimized, and the efficiency of quantum conversion is improved.



## (12)发明专利申请



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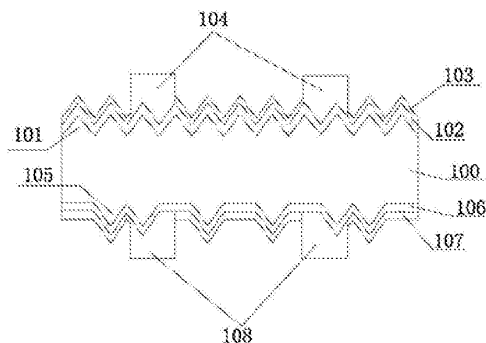
权利要求书1页 说明书4页 附图1页

### (54)发明名称

一种单晶硅双面太阳电池及其制备方法

### (57)摘要

本发明公开了一种单晶硅双面太阳电池,属于太阳电池技术领域,在单晶硅衬底的正面依次形成正面金字塔形绒面、正面掺杂发射结、正面钝化减反介质层以及正面电极,在单晶硅衬底的背面依次形成背面金字塔形绒面、背表面场、背面钝化减反介质层以及背面电极,其特征在于:所述背面金字塔形绒面为分离型金字塔形绒面,金字塔结构仅部分地覆盖单晶硅衬底,金字塔结构分散地分布在硅衬底上,被金字塔结构覆盖的区域占背面硅衬底的20%-90%。同时,本发明还公开了一种单晶硅双面太阳电池的制备方法。本发明可优化双面太阳电池的少数载流子表面复合和光学吸收特性,提高量子转换效率。



1. 一种单晶硅双面太阳能电池, 在单晶硅衬底(100)的正面依次形成正面金字塔形绒面(101)、正面掺杂发射结(102)、正面钝化减反介质层(103)以及正面电极(104), 在单晶硅衬底的背面依次形成背面金字塔形绒面(105)、背表面场(106)、背面钝化减反介质层(107)以及背面电极(108), 其特征在于: 所述背面金字塔形绒面(105)为分离型金字塔形绒面, 金字塔结构(105a)仅部分地覆盖单晶硅衬底, 金字塔结构(105a)分散地分布在硅衬底上, 被金字塔结构(105a)覆盖的区域占背面硅衬底的20%-90%。

2. 根据权利要求1所述的单晶硅双面太阳能电池, 其特征在于: 单个金字塔结构(105a)的底边长是1-7 $\mu\text{m}$ 。

3. 根据权利要求1所述的单晶硅双面太阳能电池, 其特征在于: 所述正面钝化减反介质层(103)和背面钝化减反介质层(107)分别为由氧化硅、氮化硅、氮氧化硅、氧化铝、碳化硅、非晶硅、微晶硅、氧化铟锡或者氧化钛为材料组成的单层膜或多层膜。

4. 根据权利要求1所述的单晶硅双面太阳能电池, 其特征在于: 所述正面电极(104)、背面电极(108)为银、铝、铜、镍、钛、锡、铅、镉、金、锌的一种或多种金属或其合金。

5. 一种单晶硅双面太阳能电池的制备方法, 用于制备权利要求1-4任一所述单晶硅双面太阳能电池, 包括如下步骤:

S1: 在单晶硅衬底表面制绒;

S2: 正面掺杂形成发射结;

S3: 去除背面含杂质玻璃层;

S4: 湿化学法制备背面分离金字塔形貌结构, 并去除背面掺杂层;

S5: 背面掺杂形成背表面场;

S6: 制备正面、背面钝化减反介质层;

S7: 制备正面、背面电极。

6. 根据权利要求5所述的单晶硅双面太阳能电池的制备方法, 其特征在于: 在步骤S4中, 湿化学法制备背面分离金字塔形貌结构所采用的化学药剂有氢氧化钠、氢氧化钾、四甲基氢氧化铵、硝酸、磷酸、氢氟酸、乙醇、异丙醇或乙二醇中的一种或两种以上混合的水溶液; 制备温度是60至80 $^{\circ}\text{C}$ , 时间是10-900秒。

7. 根据权利要求5所述的单晶硅双面太阳能电池的制备方法, 其特征在于: 在步骤S2和S3之间, 还包括如下步骤

S2-1: 正面沉积阻挡层: 采用PECVD在正面沉淀氧化硅薄膜的工艺阻挡层, 厚度是50至300nm。

8. 根据权利要求5所述的单晶硅双面太阳能电池的制备方法, 其特征在于: 在步骤S5和S6之间, 还包括如下步骤

S5-1: 使用氢氟酸去除正面的氧化硅、磷硅玻璃和背面的硼硅玻璃。

## 一种单晶硅双面太阳能电池及其制备方法

### 技术领域

[0001] 本发明涉及一种太阳能电池及其制备方法,尤其涉及一种单晶硅双面太阳能电池及其制备方法,属于太阳能电池技术领域。

### 背景技术

[0002] 追求提高电池转换效率,同时降低甚至维持制造成本及是业界不断追求的目标和提高自身竞争力之所在。相对于单面受光的传统晶体硅太阳能电池,双面太阳能电池利用正、背两个受光面,可以获得更高的光电流密度,很大程度地提高发电功率。根据安装地面和环境,基于双面太阳能电池的光伏发电系统可以获得10至30%的功率增益。

[0003] 双面太阳能电池结构包括:正、背面的绒面形貌结构、pn结发射极、钝化减反介质层、正、背面电极等。其中,背面的绒面可以有效地提高地面和环境反射光在双面电池背面的吸收,是双面太阳能电池的重要结构。目前双面太阳能电池的背面都采用与正面类似的绒面形貌结构,即制绒获得的金字塔分布紧密,相互交叠。虽然这种紧密分布的金字塔有利于最大限度地吸收直射光,但不一定是漫反射光的最佳光吸收结构,并且较高的表面积会带来少数载流子复合。因此,双面太阳能电池的背面结构有待进一步优化。

### 发明内容

[0004] 本发明针对现有技术中存在的上述技术问题,提供一种单晶硅双面太阳能电池,优化太阳能电池少数载流子表面负荷和光学吸收特性,提高量子转换效率。

[0005] 本发明的另一方面,提供一种单晶硅双面太阳能电池的制备方法,提高太阳能电池的转换效率和生产效率。

[0006] 为此,本发明采用如下技术方案:

一种单晶硅双面太阳能电池,在单晶硅衬底(100)的正面依次形成正面金字塔形绒面(101)、正面掺杂发射结(102)、正面钝化减反介质层(103)以及正面电极(104),在单晶硅衬底的背面依次形成背面金字塔形绒面(105)、背表面场(106)、背面钝化减反介质层(107)以及背面电极(108),其特征在于:所述背面金字塔形绒面(105)为分离型金字塔形绒面,金字塔结构(105a)仅部分地覆盖单晶硅衬底,金字塔结构(105a)分散地分布在硅衬底上,被金字塔结构(105a)覆盖的区域占背面硅衬底的20%-90%。

[0007] 进一步地,单个金字塔结构(105a)的底边长是1-7 $\mu\text{m}$ 。

[0008] 进一步地,所述正面钝化减反介质层(103)和背面钝化减反介质层(107)分别为由氧化硅、氮化硅、氮氧化硅、氧化铝、碳化硅、非晶硅、微晶硅、氧化铟锡或者氧化钛为材料组成的单层膜或多层膜。

[0009] 进一步地,所述正面电极(104)、背面电极(108)为银、铝、铜、镍、钛、锡、铅、镉、金、锌的一种或多种金属或其合金。

[0010] 本发明的另一方面,提供一种单晶硅双面太阳能电池的制备方法,用于制备所述单晶硅双面太阳能电池,包括如下步骤:

- S1:在单晶硅衬底表面制绒;
- S2:正面掺杂形成发射结;
- S3:去除背面含杂质玻璃层;
- S4:湿化学法制备背面分离金字塔形貌结构,并去除背面掺杂层;
- S5:背面掺杂形成背表面场;
- S6:制备正面、背面钝化减反介质层;
- S7:制备正面、背面电极。

[0011] 在步骤S4中,湿化学法制备背面分离金字塔形貌结构所采用的化学药剂有氢氧化钠、氢氧化钾、四甲基氢氧化铵、硝酸、磷酸、氢氟酸、乙醇、异丙醇或乙二醇中的一种或两种以上混合的水溶液;制备温度是60至80℃,时间是10-900秒。

[0012] 进一步地,在步骤S2和S3之间,还可以包括如下步骤:S2-1:正面沉积阻挡层。

[0013] 进一步地,在步骤S5和S6之间,还包括如下步骤:S5-1:使用氢氟酸去除正面的氧化硅、磷硅玻璃和背面的硼硅玻璃。

[0014] 本发明的单晶硅双面太阳能电池,通过在电池的背面设置分离型金字塔形绒面,减少太阳能电池背面绒面的表面积,明显地降低光生少数载流子在背表面的复合;正面入射的长波长光在背表面的反射增加,透射减小,重新被太阳能电池吸收;同时,背面覆有减反介质层,背面的光学反射没有明显增加,保证背面的光学吸收特性。因此,通过背面分离金字塔形貌结构,可以优化双面太阳能电池的少数载流子表面复合和光学吸收特性,提高量子转换效率。

[0015] 本发明的单晶硅双面太阳能电池的制备方法,仅仅增加一道湿化学方法制备背面分离金字塔形貌结构,工艺相对简单,适合于低成本、大批量、稳定的工业制造。

#### 附图说明

[0016] 图1为本发明的单晶硅双面太阳能电池的结构示意图;

图2为本发明的分离型金字塔形绒面的显微镜照片;

其中,100为单晶硅衬底,101为正面金字塔形绒面,102为正面掺杂发射结,103为正面钝化减反介质层,104为正面电极,105为背面金字塔形绒面,105a为金字塔结构,106为背表面场,107为背面钝化减反介质层,108为背面电极,109为未被金字塔结构覆盖的区域;图中相应的产品结构仅为示意图,未按比例绘制。

#### 具体实施方式

[0017] 为了使本技术领域的人员更好的理解本发明方案,下面将结合本发明实施例中的附图,对本发明实施例中的技术方案进行清楚、完整的描述。

[0018] 实施例1:

本实施例是本发明应用于P型单晶硅的情形。如图1所示,在P型单晶硅衬底100的正面依次形成正面金字塔形绒面101、正面磷掺杂发射结102、正面钝化减反介质层103以及正面电极104,在P型单晶硅衬底的背面依次形成背面分离型金字塔形绒面105、背面硼掺杂形成的硼掺杂背表面场106、背面钝化减反介质层107以及背面电极108,其中,如图2所示,背面分离型金字塔形绒面105中,金字塔结构105a仅部分地覆盖单晶硅衬底,金字塔结构105a分

散地分布在单晶硅衬底的背面,留下一些未被金字塔结构覆盖的区域109。

[0019] 在本实施例中,被金字塔结构105a覆盖的区域占整个背面硅衬底的85%,单个金字塔结构105a的底边长是 $5\mu\text{m}$ ;正面钝化减反介质层103为由氮化硅制成的单层膜,膜厚70至80nm;背面钝化减反介质层107为由氧化铝和氮化硅制成的双层膜,其中,氧化铝膜厚20至30nm和氮化硅膜厚50至70nm。正面电极104和背面电极108均为银栅电极。

[0020] 实施例2:

本实施例与实施例1的不同之处在于:背面分离型金字塔形绒面105中,被金字塔结构105a覆盖的区域占整个背面硅衬底的50%,单个金字塔结构105a的底边长是 $7\mu\text{m}$ 。正面钝化减反介质层103为由氮氧化硅制成的单层膜,膜厚70至80nm;背面钝化减反介质层107为由氧化钛和氧化硅制成的双层膜,其中,氧化钛膜厚20至30nm和氧化硅膜厚50至70nm。正面电极104和背面电极108均为铜电极。

[0021] 实施例3:

本实施例是本发明应用于N型单晶硅的情形。如图1所示,在N型单晶硅衬底100的正面依次形成正面金字塔形绒面101、正面掺磷掺杂发射结102、正面钝化减反介质层103以及正面电极104,在N型单晶硅衬底的背面依次形成背面分离型金字塔形绒面105、背面磷掺杂形成的磷掺杂背表面场106、背面钝化减反介质层107以及背面电极108,其中,背面分离型金字塔形绒面105中,金字塔结构105a仅部分地覆盖单晶硅衬底,金字塔结构105a分散地分布在单晶硅衬底的背面,被金字塔结构105a覆盖的区域占整个背面硅衬底的30%,单个金字塔结构105a的底边长是 $2\mu\text{m}$ 。

[0022] 在本实施例中,正面钝化减反介质层103为由氧化铝和氮化硅制成的双层膜,其中,氧化铝膜厚20至30nm和氮化硅膜厚50至70nm;背面钝化减反介质层107为氮化硅制成的单层膜,膜厚70至80nm;正面电极104和背面电极108均为银栅电极。

[0023] 实施例4:

本实施例与实施例3的不同之处在于:背面分离型金字塔形绒面105中,被金字塔结构105a覆盖的区域占整个背面硅衬底的65%,单个金字塔结构105a的底边长是 $4\mu\text{m}$ 。正面钝化减反介质层103为由氧化铟锡和非晶硅制成的双层膜,其中,氧化铟锡膜厚60至80nm和非晶硅膜厚5至20nm;背面钝化减反介质层107为氧化铟锡和非晶硅制成的双层膜,其中,氧化铟锡膜厚60至80nm和非晶硅膜厚5至20nm;正面电极104和背面电极108均为银电极。

[0024] 实施例5:

一种单晶硅双面太阳能电池的制备方法,用于制备实施例1所述的P单晶硅双面太阳能电池,包括如下步骤:

S1:在单晶硅衬底表面制绒:使用含氢氧化钠和异丙醇的碱性制绒液,温度是 $80^{\circ}\text{C}$ ,对p型单晶硅衬底100表面进行制绒,形成正面金字塔形绒面101,同时去除硅片切割损伤层;

S2:正面掺杂形成发射结:进行磷掺杂形成正面掺杂发射结102,磷掺杂可以采用三氯氧磷源的管式炉扩散、离子注入或涂覆含磷杂质层的扩散,扩散方阻是40至 $200\Omega/\square$ ;

S2-1:正面沉积阻挡层:采用PECVD在正面沉积氧化硅薄膜的工艺阻挡层,厚度是50至300nm;

S3:去除背面含杂质玻璃层:使用氢氟酸去除背面的磷硅玻璃层;

S4:湿化学法制备背面分离型金字塔形绒面,并去除背面掺杂:使用含四甲基氢氧化铵

和异丙醇的碱性药液,温度是80℃,时间是10至900s,制备形成背面分离型金字塔形绒面105,同时去除背面磷掺杂层;

S5:背面掺杂形成背表面场:进行硼掺杂形成背表面场106,硼掺杂可以采用三溴化硼源的管式炉扩散、离子注入或涂覆含硼杂质层的扩散,扩散方阻是60至200  $\Omega/\square$ ;

S5-1:使用氢氟酸去除正面的氧化硅、磷硅玻璃和背面的硼硅玻璃;

S6:制备正面、背面钝化减反介质层:采用PECVD制备正面氮化硅103和背面氧化铝/氮化硅的钝化减反介质层107;正面氮化硅厚度是70至80nm,背面氧化铝厚度是20至30nm,氮化硅厚度是50至70nm;

S7:制备正、背面电极:采用丝网印刷分别在正、背面制备含银栅线电极104和108,并进行高温烧结,烧结温度是850至900℃。

[0025] 当然,在步骤S4中,也可以采用含硝酸和氢氟酸的酸性药液制备背面分离型金字塔形绒面。

[0026] 实施例2的制备方法参照实施例1的制备方法。

[0027] 实施例6:

一种单晶硅双面太阳能电池的制备方法,用于制备实施例3所述的N单晶硅双面太阳能电池,包括如下步骤:

S1:在单晶硅衬底表面制绒:使用含氢氧化钠和异丙醇的碱性制绒液,温度是80℃,对n型单晶硅衬底100表面进行制绒,形成正面绒面形貌101,同时去除硅片切割损伤层;

S2:正面掺杂形成发射结:进行硼掺杂形成正面硼掺杂发射结102,磷掺杂可以采用三溴化硼源的管式炉扩散、离子注入或涂覆含硼杂质层的扩散,扩散方阻是60至200  $\Omega/\square$ ;

S2-1:正面沉积阻挡层:采用PECVD在正面沉积氧化硅薄膜的工艺阻挡层,厚度是50至300nm;

S3:去除背面含杂质玻璃层:使用氢氟酸去除背面的硼硅玻璃层;

S4:湿化学法制备背面分离型金字塔形绒面,并去除背面掺杂:使用含四甲基氢氧化铵和异丙醇的碱性药液,温度是80℃,时间是10至900s,制备背面金字塔形绒面105,同时去除背面硼掺杂层;

S5:背面掺杂形成背表面场:进行磷掺杂形成背表面场106,磷掺杂可以采用三氯氧磷源的管式炉扩散、离子注入或涂覆含磷杂质层的扩散,扩散方阻是40至200  $\Omega/\square$ ;

S5-1:使用氢氟酸去除正面的氧化硅、硼硅玻璃和背面的磷硅玻璃;

S6:制备正面、背面钝化减反介质层:采用PECVD制备正面氧化铝/氮化硅,103和背面氮化硅的钝化减反介质层107;正面氧化铝厚度是20至30nm,氮化硅厚度是50至70nm;背面氮化硅厚度是70至80nm;

S7:制备正、背面电极:采用丝网印刷分别在正、背面制备含银栅线电极104和108,并进行高温烧结,烧结温度是850至900℃。

[0028] 实施例4的制备方法参照实施例3的制备方法。

[0029] 显然,所描述的实施例仅仅是本发明的部分实施例,而不是全部的实施例。基于本发明中的实施例,本领域普通技术人员在没有做出创造性劳动前提下所获得的所有其他实施例,都应当属于本发明保护的范围。

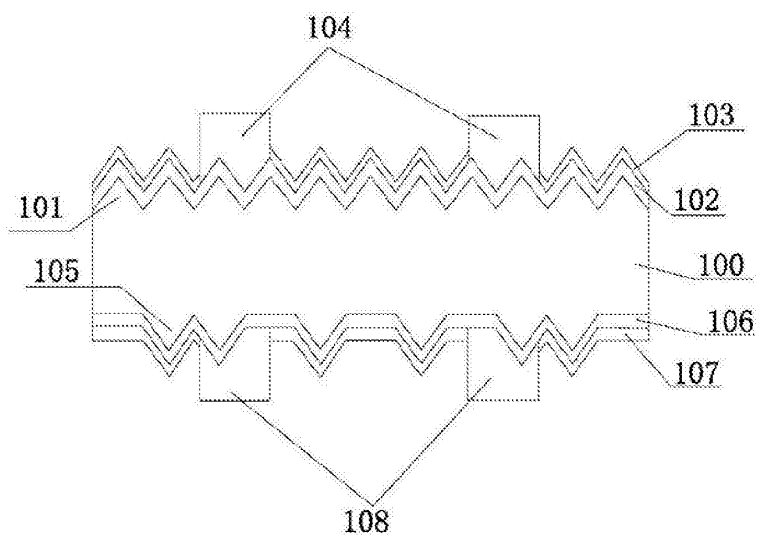


图1

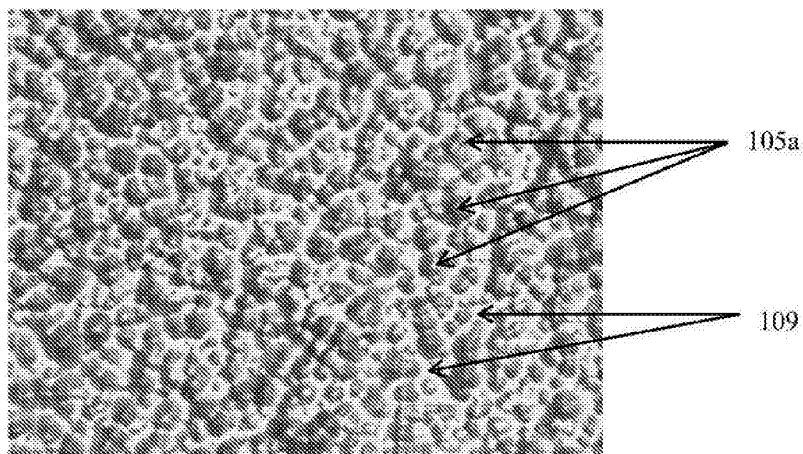


图2



Espacenet

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Single crystal silicon-based inverted pyramid textured structure back passivation solar cell and preparation method thereof

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Abstract of CN109545880 (A)

A single crystal silicon-based inverted pyramid textured structure back passivation solar cell belongs to the technical field of solar cells. The cell includes a single crystal silicon substrate, the front surface of the single crystal silicon substrate adopts a silicon-based inverted pyramid structure emitter, and the back surface of the single crystal silicon substrate adopts a back passivation structure; the silicon-based inverted pyramid structure emitter is composed of a silicon inverted pyramid structure and two layers of passivation dielectric films; and the invention also relates to a preparation method of the single crystal silicon-based inverted pyramid textured structure back passivation solar cell. The solar cell optimizes spectral response of the cell in a short-wavelength band and a long-wavelength band, achieves excellent spectral response of the silicon-based solar cell in an entire wavelength band (300-1100 nm), finally achieves improvement of the efficiency of the solar cell, and achieves photoelectric conversion efficiency of 22.09% on an n-type standard solar cell with the size of 156\*156 mm<sup>2</sup>.



## (12)发明专利申请



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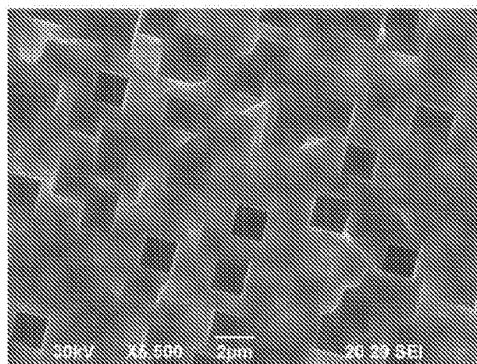
权利要求书2页 说明书5页 附图4页

### (54)发明名称

一种单晶硅基类倒金字塔绒面结构背钝化  
太阳电池及其制备方法

### (57)摘要

一种单晶硅基类倒金字塔绒面结构背钝化太阳电池,属于太阳能电池技术领域,该电池包括单晶硅基底,单晶硅基底的正表面采用硅基类倒金字塔结构发射极,单晶硅基底的背表面采用背钝化结构;所述硅基类倒金字塔结构发射极由硅类倒金字塔结构和2层钝化介质膜构成;本发明还涉及单晶硅基类倒金字塔结构背钝化太阳电池的制备方法。本发明是优化电池在短波段和长波段的光谱响应,实现硅基太阳电池在整个波段(300—1100nm)上的优异光谱响应,最终实现太阳电池效率的提高,在n型标准太阳电池尺寸 $156 \times 156 \text{ mm}^2$ 上实现了22.09%的光电转换效率。



1. 一种单晶硅基类倒金字塔绒面结构背钝化太阳电池,其特征在于:该电池包括单晶硅基底,单晶硅基底的正表面采用硅基类倒金字塔结构发射极,单晶硅基底的背表面采用背钝化结构;所述硅基类倒金字塔结构发射极由硅类倒金字塔结构和2层钝化介质膜构成。

2. 根据权利要求1所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,其特征在于:所述硅类倒金字塔结构由{111}晶面族的8个面组成。

3. 根据权利要求1或2所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,其特征在于:所述硅类倒金字塔结构上开口边长 $2\mu\text{m}$ — $3\mu\text{m}$ ,优选 $2.7\mu\text{m}$ ,斜面与底面夹角为 $52^\circ$ — $58^\circ$ ,优选 $54.7^\circ$ ,深度为 $1\mu\text{m}$ — $3\mu\text{m}$ ,优选 $2\mu\text{m}$ 。

4. 根据权利要求1所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,其特征在于:所述2层钝化介质膜中:内层钝化介质膜为PECVD沉积的 $\text{SiO}_2$ 薄膜,厚度为 $9.5\text{nm}$ — $10.5\text{nm}$ ,优选 $10\text{nm}$ ,外层钝化介质膜为PECVD沉积的 $\text{SiN}_x$ ( $x$ 为正数,下同)薄膜,厚度为 $66\text{nm}$ — $74\text{nm}$ ,优选 $70\text{nm}$ 。

5. 根据权利要求1所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,其特征在于:所述背钝化结构采用 $\text{TiO}_2/\text{SiN}_x$ 叠层钝化。

6. 根据权利要求1或5所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,其特征在于:所述背钝化结构由2层钝化介质膜组成,内层钝化介质膜为ALD沉积的 $\text{TiO}_2$ 薄膜,厚度为 $3\text{nm}$ — $8\text{nm}$ ,优选 $5\text{nm}$ ;外层钝化介质膜为PECVD沉积的 $\text{SiN}_x$ 薄膜,厚度为 $240\text{nm}$ — $260\text{nm}$ ,优选 $250\text{nm}$ 。

7. 一种单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法,其特征在于:其步骤如下:

(1) 硅片准备:采用n型面切割的、太阳级的Cz硅片作基材,将硅片进行RCA标准工艺清洗,得到单晶硅基底;

(2) 多孔硅制备:在由 $\text{HF}$ 、 $\text{AgNO}_3$ 、 $\text{H}_2\text{O}_2$ 组成的混合液中,采用MACE即金属辅助化学刻蚀方法在单晶硅基底正表面刻蚀多孔硅结构,刻蚀时间55秒—65秒,再用 $\text{HNO}_3$ 溶液将残余的银清洗干净;混合液中: $\text{HF}$ 的浓度为 $1.95\text{M}$ — $2.05\text{M}$ , $\text{AgNO}_3$ 的浓度为 $0.0045\text{M}$ — $0.0055\text{M}$ , $\text{H}_2\text{O}_2$ 的浓度为 $1.02\text{M}$ — $1.08\text{M}$ ;

(3) 酸修饰:将带有多孔的硅片在 $6^\circ\text{C}$ — $9^\circ\text{C}$ 的 $\text{HF}/\text{HNO}_3=1:3$ (vol)混合酸溶液中,刻蚀85s—95s,将表面一层多孔硅去除,同时将底部的纳米孔洞结构进行“扩孔”;

(4) 类倒金字塔结构制备:将“扩孔”后的硅片放进 $76^\circ\text{C}$ — $84^\circ\text{C}$ 的 $\text{NaOH}$ 溶液中,进行各向异性刻蚀,得到分布均匀的类倒金字塔结构;

(5)  $\text{p}^+$ 发射极制备:将带有类倒金字塔结构的硅片放入石英扩散管中,在 $900^\circ\text{C}$ — $980^\circ\text{C}$ 的条件下,采用硼酸三甲酯热扩散的方法扩散40min—52min,在硅片表面形成硅基类倒金字塔结构 $\text{p}^+$ 发射极;

(6) 背表面处理:在单晶硅基底背表面经过碱工艺抛光后,用ALD原子层沉积方法,在硅片背表面沉积叠层钝化膜 $\text{TiO}_2/\text{SiN}_x$ ,沉积温度为 $430^\circ\text{C}$ — $470^\circ\text{C}$ ,沉积时间58分钟—64分钟, $\text{TiO}_2$ 沉积源为TDMAT, $\text{SiN}_x$ 沉积源为 $\text{NH}_4$ 和 $\text{SiH}_4$ ;

(7) 正表面处理:将正面的磷硅玻璃用 $4.5\%$ — $6.5\%$ 的稀 $\text{HF}$ 溶液去掉后,继续用PECVD化学沉积方法,在硅片正面沉积叠层钝化膜 $\text{SiO}_2/\text{SiN}_x$ ,沉积温度为 $430^\circ\text{C}$ — $470^\circ\text{C}$ ,沉积时间58分钟—64分钟;

(8) 背表面开口: 在沉积 $\text{TiO}_2$  / $\text{SiN}_x$ 叠层钝化膜后的背表面, 采用激光开窗的方式, 在叠层膜上形成线状开口, 露出单晶硅基底;

(9) 成品: 通过丝网印刷工艺, 印刷正面银电极、背电极以及背面铝浆, 再经过烧结, 形成正面、背面欧姆接触以及铝背场, 即得。

8. 根据权利要求7所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法, 其特征在于: 步骤(2)的混合液中:  $\text{HF}$ 的浓度为 $2\text{M}$ ,  $\text{AgNO}_3$  的浓度为 $0.005\text{M}$ ,  $\text{H}_2\text{O}_2$ 的浓度为 $1.06\text{M}$ ; 步骤(4)中将带有多孔的硅片放进 $80^\circ\text{C}$ 的 $\text{NaOH}$ 溶液中进行各向异性刻蚀; 步骤(5)中: 在 $950^\circ\text{C}$ 的条件下, 采用硼酸三甲酯热扩散的方法扩散 $50\text{min}$ , 在硅片表面形成硅基类倒金字塔结构 $\text{p}^+$ 发射极; 步骤(6)和(7)中: 沉积温度为 $450^\circ\text{C}$ , 沉积时间分钟60分钟。

9. 根据权利要求7所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法, 其特征在于: 步骤(8)背表面开口的的方法是: 在沉积后的背表面, 采用波长 $532\text{nm}$ 脉冲宽度 $10\text{ps}$ 的激光, 在 $\text{TiO}_2$  / $\text{SiN}_x$ 叠层钝化膜上形成 $50\mu\text{m}$ 宽 $1\text{mm}$ 周期的线状开口。

10. 根据权利要求7所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法, 其特征在于: 步骤(6)中, 背表面 $\text{ALD-TiO}_2$ 薄膜, 用热氧化方法取代 $\text{ALD}$ 沉积; 步骤(7)中, 正表面 $\text{PECVD-SiO}_2$ 薄膜, 用热氧化方法取代 $\text{PECVD}$ 沉积。

## 一种单晶硅基类倒金字塔绒面结构背钝化太阳电池及其制备方法

### 技术领域

[0001] 本发明涉及一种太阳能电池,特别是一种单晶硅基类倒金字塔绒面结构背钝化太阳电池,还涉及上述单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法。

### 背景技术

[0002] 提高效率是太阳电池研究和生产的永恒主题,而提高太阳电池效率的本质是提升器件的光谱响应性能。现有商业化生产的大面积晶硅太阳电池由于前表面剩余反射和背表面复合损失,在光谱的短波段和长波段光谱响应仍有人幅提升的空间。因此,对商业晶硅太阳电池的前后表面进行先进技术的替代在所难免。

[0003] 传统单晶硅太阳电池技术方案是:以单晶硅为基底,正面刻蚀金字塔结构,金字塔上覆盖PECVD— $\text{SiN}_x$  ( $x$ 为正数)钝化薄膜,正面、背面采用丝网印刷正银、铝浆和背电极,通过烧结工艺,实现正面欧姆接触和铝背场,缺点是电池器件在短波段(300—450 nm)和长波段(900—1100 nm)的光谱响应不高,还有进一步提升的空间,主要原因是,正面金字塔结构的减反射能力一般,导致在短波段的外量子效率不高;背面铝背场表面复合速率较大,导致电池在长波段的外量子效率较低。

### 发明内容

[0004] 本发明所要解决的技术问题是针对现有技术的不足,提供一种优化电池在短波段和长波段的光谱响应,提高太阳电池效率的单晶硅基类倒金字塔绒面结构背钝化太阳电池。

[0005] 本发明所要解决的另一个技术问题是提供了上述单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法。

[0006] 本发明所要解决的技术问题是通过以下的技术方案来实现的。本发明是一种单晶硅基类倒金字塔绒面结构背钝化太阳电池,该电池包括单晶硅基底,单晶硅基底的正表面采用硅基类倒金字塔结构发射极,单晶硅基底的背表面采用背钝化结构;所述硅基类倒金字塔结构发射极由硅类倒金字塔结构和2层钝化介质膜构成。

[0007] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,所述硅类倒金字塔结构由{111}晶面族的8个面组成。

[0008] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,所述硅类倒金字塔结构上开口边长 $2\mu\text{m}$ — $3\mu\text{m}$ ,优选 $2.7\mu\text{m}$ ,斜面与底面夹角为 $52^\circ$ — $58^\circ$ ,优选 $54.7^\circ$ ,深度为 $1\mu\text{m}$ — $3\mu\text{m}$ ,优选 $2\mu\text{m}$ 。

[0009] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,所述2层钝化介质膜中:内层钝化介质膜为PECVD沉积的 $\text{SiO}_2$ 薄膜,厚度为 $9.5\text{nm}$ — $10.5\text{nm}$ ,优选 $10\text{ nm}$ ,外层钝化介质膜为PECVD

沉积的 $\text{SiN}_x$  ( $x$ 为正数,下同)薄膜,厚度为66nm—74nm,优选70 nm。

[0010] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,所述背钝化结构采用 $\text{TiO}_2/\text{SiN}_x$ 叠层钝化。

[0011] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池,所述背钝化结构由2层钝化介质膜组成,内层钝化介质膜为ALD沉积的 $\text{TiO}_2$ 薄膜,厚度为3nm—8nm,优选5 nm;外层钝化介质膜为PECVD沉积的 $\text{SiN}_x$ 薄膜,厚度为240nm—260nm,优选250 nm。

[0012] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,本发明还公开了以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法,其步骤如下:

(1) 硅片准备:采用n型面切割的、太阳级的Cz硅片作基材,将硅片进行RCA标准工艺清洗,得到单晶硅基底;

(2) 多孔硅制备:在由 $\text{HF}$ 、 $\text{AgNO}_3$ 、 $\text{H}_2\text{O}_2$ 组成的混合液中,采用MACE即金属辅助化学刻蚀方法在单晶硅基底正表面刻蚀多孔硅结构,刻蚀时间55秒—65秒,再用 $\text{HNO}_3$ 溶液将残余的银清洗干净;混合液中: $\text{HF}$ 的浓度为1.95M—2.05M, $\text{AgNO}_3$ 的浓度为0.0045M—0.0055M, $\text{H}_2\text{O}_2$ 的浓度为1.02M—1.08M;

(3) 酸修饰:将带有多孔的硅片在6℃—9℃的 $\text{HF}/\text{HNO}_3=1:3$  (v/v) 混合酸溶液中,刻蚀85s—95s,将表面一层多孔硅去除,同时将底部的纳米孔洞结构进行“扩孔”。

[0013] (4) 类倒金字塔结构制备:将“扩孔”后的硅片放进76℃—84℃的 $\text{NaOH}$ 溶液中,进行各向异性刻蚀,得到分布均匀的类倒金字塔结构;

(5)  $\text{p}^+$ 发射极制备:将带有类倒金字塔结构的硅片放入石英扩散管中,在900℃—980℃的条件下,采用硼酸三甲酯热扩散的方法扩散40 min—52 min,在硅片表面形成硅基类倒金字塔结构 $\text{p}^+$ 发射极;

(6) 背表面处理:在单晶硅基底背表面经过碱工艺抛光后,用ALD原子层沉积方法,在硅片背表面沉积叠层钝化膜 $\text{TiO}_2/\text{SiN}_x$ ,沉积温度为430℃—470℃,沉积时间58分钟—64分钟, $\text{TiO}_2$ 沉积源为TDMAT, $\text{SiN}_x$ 沉积源为 $\text{NH}_4$ 和 $\text{SiH}_4$ ;

(7) 正表面处理:将正面的磷硅玻璃用4.5%—6.5%的稀 $\text{HF}$ 溶液去掉后,继续用PECVD化学沉积方法,在硅片正面沉积叠层钝化膜 $\text{SiO}_2/\text{SiN}_x$ ,沉积温度为430℃—470℃,沉积时间58分钟—64分钟;

(8) 背表面开口:在沉积 $\text{TiO}_2/\text{SiN}_x$ 叠层钝化膜后的背表面,采用激光开窗的方式,在叠层膜上形成线状开口,露出单晶硅基底;

(9) 成品:通过丝网印刷工艺,印刷正面银电极、背电极以及背面铝浆,再经过烧结,形成正面、背面欧姆接触以及铝背场,即得。

[0014] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法,步骤(2)的混合液中: $\text{HF}$ 的浓度为2M, $\text{AgNO}_3$ 的浓度为0.005M, $\text{H}_2\text{O}_2$ 的浓度为1.06M;步骤(4)中将带有多孔的硅片放进80℃的 $\text{NaOH}$ 溶液中进行各向异性刻蚀;步骤(5)中:在950℃的条件下,采用硼酸三甲酯热扩散的方法扩散50 min,在硅片表面形成硅基类倒倒金字塔结构 $\text{p}^+$ 发射极;步骤(6)和(7)

中:沉积温度为450℃,沉积时间分钟60分钟。

[0015] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳能电池的制备方法,步骤(8)背表面开口的方法是:在沉积后的背表面,采用波长532nm脉冲宽度10ps的激光,在TiO<sub>2</sub>/SiN<sub>x</sub>叠层钝化膜上形成50μm宽1mm周期的线状开口。

[0016] 本发明所要解决的技术问题还可以通过以下的技术方案来进一步实现,对于以上所述的单晶硅基类倒金字塔绒面结构背钝化太阳能电池的制备方法,步骤(6)中,背表面ALD—TiO<sub>2</sub>薄膜,用热氧化方法取代ALD沉积,厚度6nm;步骤(7)中,正表面PECVD—SiO<sub>2</sub>薄膜,用热氧化方法取代PECVD沉积,厚度8nm—10nm。

[0017] 本发明单晶硅基类倒金字塔结构背钝化太阳能电池将硅类倒金字塔结构和背表面钝化结合起来,能够在短波段和长波段提供互补的光谱响应,这意味着一种非常有效的实现太阳能电池器件在全波段上优异的光谱响应。本发明中,电池背面采用ALD—TiO<sub>2</sub>/PECVD—SiN<sub>x</sub>叠层背钝化结构;正面的硅基类倒金字塔绒面结构具有比传统更好的短波减反射能力、更好的发射极复合损失抑制;TiO<sub>2</sub>/SiN<sub>x</sub>叠层背钝化结构使电池具有更高的内背反射率以及更低的表面复合速率;由于以上电池结构的优化,使这种新颖的硅基类倒金字塔绒面结构背钝化太阳能电池在全波段上实现了优异光谱响应,在n型标准太阳能电池尺寸156×156mm<sup>2</sup>上实现了22.09%的光电转换效率。

[0018] 与现有技术相比,本发明是优化电池在短波段和长波段的光谱响应,实现硅基太阳能电池在整个波段(300—1100nm)上的优异光谱响应,最终实现太阳能电池效率的提高,同时保证了正面(短波)和背面(长波)的优异光电性能。

#### 附图说明

[0019] 图1为本发明中硅类倒金字塔结构扫描电镜图;

图2为本发明中硅类倒金字塔结构扫描电镜放大图;

图3为本发明中硅类倒金字塔结构酸修饰前的扫描电镜图;

图4为本发明中硅类倒金字塔结构酸修饰后的扫描电镜图;

图5为本发明太阳能电池结构示意图;

图6为与传统正金字塔太阳能电池相比,本发明太阳能电池的光谱响应优势图;

图7为本发明太阳能电池的I—V和P—V输出特性图。

#### 具体实施方式

[0020] 为使本发明实施例的目的、技术方案和优点更加清楚,下面将结合本发明附图,对本发明实施例中的技术方案进行清楚、完整地描述,显然,所描述的实施例是本发明一部分实施例,而不是全部的实施例。基于本发明中的实施例,本领域普通技术人员在没有做出创造性劳动前提下所获得的所有其他实施例,都属于本发明保护的范围。

[0021] 参照图1—4,一种硅基类倒金字塔绒面结构背钝化太阳能电池,包括n型单晶硅基底1、所述单晶硅前表面的类倒金字塔结构发射极5和所述单晶硅基底1背表面的背钝化结构;所述硅基类倒金字塔绒面结构发射极5由类倒金字塔绒面结构和2层钝化介质膜PECVD—SiO<sub>2</sub>/SiN<sub>x</sub>(x为正数,下同)构成;所述类倒金字塔绒面结构由{111}晶面族的8个面组成,而

普通倒金字塔由{111}晶面族的4个面组成;类倒金字塔绒面结构上开口边长为 $2.7\mu\text{m}$ 左右,斜面与底面夹角为 $54.7^\circ$ ,深度为 $2\mu\text{m}$ 左右;所述2层钝化介质膜,内层钝化介质膜为PECVD沉积的 $\text{SiO}_2$ 薄膜2,厚度为 $10\text{ nm}$ 左右,外层钝化介质膜为PECVD沉积的 $\text{SiN}_x$ 薄膜3,厚度为 $70\text{ nm}$ 左右;

所述背钝化结构由2层钝化介质膜组成,内层钝化介质膜为ALD沉积的 $\text{TiO}_2$ 薄膜8,厚度为 $5\text{ nm}$ 左右;外层钝化介质膜为PECVD沉积的 $\text{SiN}_x$ 薄膜7,厚度为 $250\text{ nm}$ 左右。

[0022] 一种单晶硅基类倒金字塔绒面结构背钝化太阳电池的制备方法,其步骤如下:先对n型单晶硅片进行RCA标准清洗;在 $\text{HF}(2\text{ M})/\text{AgNO}_3(0.0005\text{ M})/\text{H}_2\text{O}_2(1.06\text{ M})$ 混合液中,采用MACE(金属辅助化学刻蚀)技术,刻蚀纳米多孔硅结构;在 $6-9^\circ\text{C}$ 的 $\text{HF}/\text{HNO}_3=1:3(\text{vol})$ 混合酸溶液中,去除多孔硅,同时对底部的纳米孔洞结构进行“扩孔”;将经过“扩孔”的硅片放进 $80^\circ\text{C}$ 的 $\text{NaOH}$ 溶液中,进行各向异性刻蚀,得到分布均匀的硅基类倒金字塔绒面结构;将带有类倒金字塔结构的硅片放入石英扩散管中,在 $950^\circ\text{C}$ 的条件下,采用硼酸三甲酯热扩散的方法扩散 $50\text{ min}$ ,形成硅基类倒金字塔绒面结构 $\text{p}^+$ 发射极;然后采用碱工艺对电池背面进行抛光,采用PECVD化学沉积技术,形成叠层钝化膜PECVD— $\text{SiO}_2/\text{SiN}_x$ ;用5%的稀 $\text{HF}$ 溶液去除硼硅玻璃,采用PECVD化学沉积技术,在正面沉积叠层钝化膜PECVD— $\text{SiO}_2/\text{SiN}_x$ ;电池背面激光开窗,采用波长 $532\text{nm}$ 脉冲宽度 $10\text{ ps}$ 的激光,开窗形状为线状,开窗尺寸为宽 $40\mu\text{m}$ ,间隔 $1\text{ mm}$ ;丝网印刷正面银电极4、背电极以及背面铝浆6,最后再经过烧结,形成正面、背面欧姆接触以及铝背场。

[0023] 本发明的具体实施方案如下:采用n型(100)面、 $156\times 156\text{ mm}^2$ 尺寸(膺平方)、太阳级的Cz硅片,硅片厚度 $190\pm 10\mu\text{m}$ ,电阻率 $\sim 3\ \Omega\text{ cm}$ 。

[0024] 制备过程如下:

- ① 硅片RCA标准工艺清洗;
- ② 多孔硅制备,在 $\text{HF}(2\text{ M})/\text{AgNO}_3(0.0005\text{ M})/\text{H}_2\text{O}_2(1.06\text{ M})$ 混合液中,采用MACE(金属辅助化学刻蚀)在硅片表面刻蚀纳米多孔硅结构,刻蚀时间 $6\text{ min}$ ,再用 $\text{HNO}_3$ 溶液将残余的银清洗干净;
- ③ 酸修饰,在 $6-9^\circ\text{C}$ 的 $\text{HF}/\text{HNO}_3=1:3(\text{vol})$ 混合酸溶液中,刻蚀 $1\text{ min } 30\text{ s}$ ,将表面一层多孔硅去除,同时将底部的纳米孔洞结构进行“扩孔”;
- ④ 硅基类倒金字塔绒面结构制备,将经过“扩孔”的硅片放进 $80^\circ\text{C}$ 的 $\text{NaOH}$ 溶液中,进行各向异性刻蚀,得到分布均匀的类倒金字塔结构;
- ⑤ 将带有硅基类倒金字塔绒面结构的硅片放入石英扩散管中,在 $950^\circ\text{C}$ 的条件下,采用硼酸三甲酯热扩散的方法扩散 $50\text{ min}$ ,在硅片表面形成硅基类倒金字塔绒面结构 $\text{p}^+$ 发射极;
- ⑥ 碱工艺抛光背面,用原子层沉积(ALD)技术在硅片背表面沉积 $\text{TiO}_2$ 钝化层,然后覆盖一层PECVD— $\text{SiN}_x$ 膜;ALD沉积源为TDMAT,TDMAT为四(二甲氨基)钛,沉积温度为 $150^\circ\text{C}$ ,沉积10个循环,大约 $5\text{ nm}$ ;PECVD沉积温度为 $450^\circ\text{C}$ ,沉积时间 $60\text{ min}$ , $\text{SiN}_x$ 沉积源为 $\text{NH}_4$ 和 $\text{SiH}_4$ ;
- ⑦ 硼硅玻璃清洗,用5%的稀 $\text{HF}$ 溶液去掉后,继续用PECVD化学沉积方法,在硅片正面沉积叠层钝化膜 $\text{SiO}_2/\text{SiN}_x$ ,沉积温度为 $450^\circ\text{C}$ ,沉积时间 $60\text{ min}$ ;

⑧ 采用波长532nm脉冲宽度10 ps 的激光,在背面TiO<sub>2</sub>/SiN<sub>x</sub>叠层钝膜上形成50μm宽1mm周期的线状开口;

⑨ 通过丝网印刷工艺,印刷正面银电极、背电极以及背面铝浆,再经过烧结,形成正面、背面欧姆接触。

[0025] 本发明技术方案带来的有益效果:

电池正面陷光结构采用硅基类倒金字塔,电池背面采用ALD—TiO<sub>2</sub>/PECVD—SiN<sub>x</sub>叠层背钝化结构;正面的硅基类倒金字塔绒面结构具有比传统更好的短波减反射能力、更好的发射极复合损失抑制;TiO<sub>2</sub>/SiN<sub>x</sub>叠层背钝化结构使电池具有更高的内背反射率以及更低的表面复合速率,由于以上电池结构的优化,使这种新颖的硅基类倒金字塔绒面结构背钝化太阳能电池在全波段上实现了优异光谱响应,光电转换效率达到22.09%。

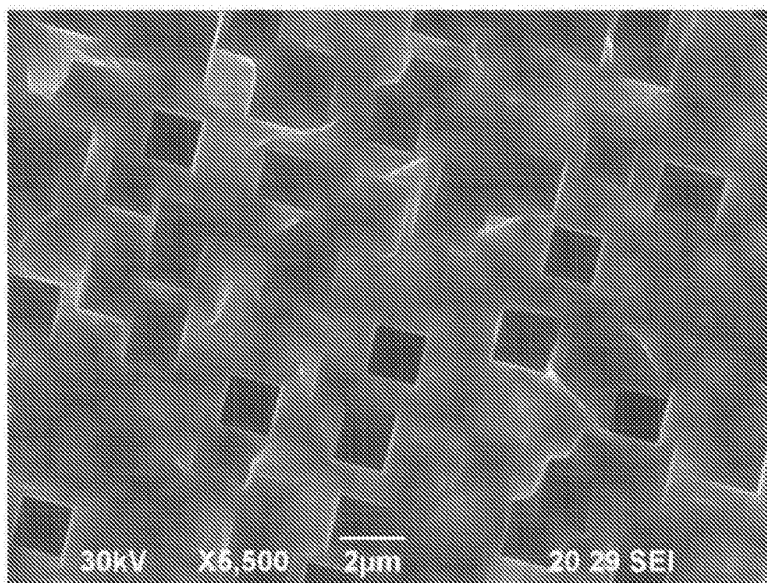


图1

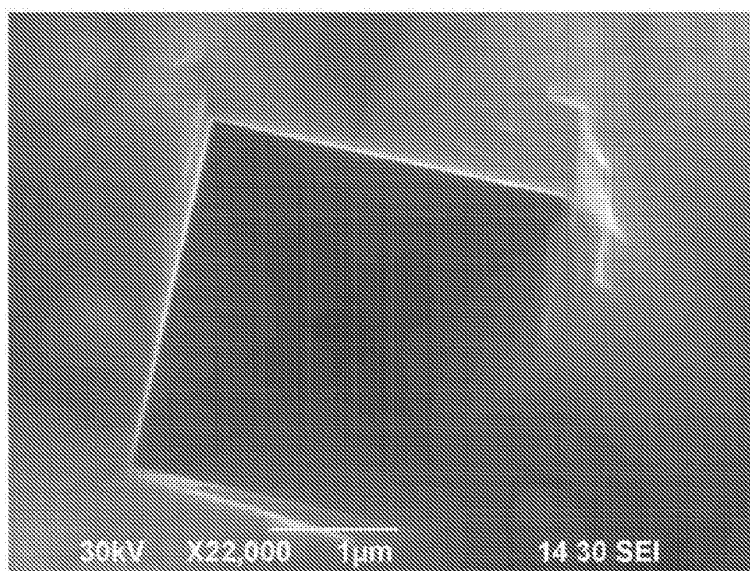


图2

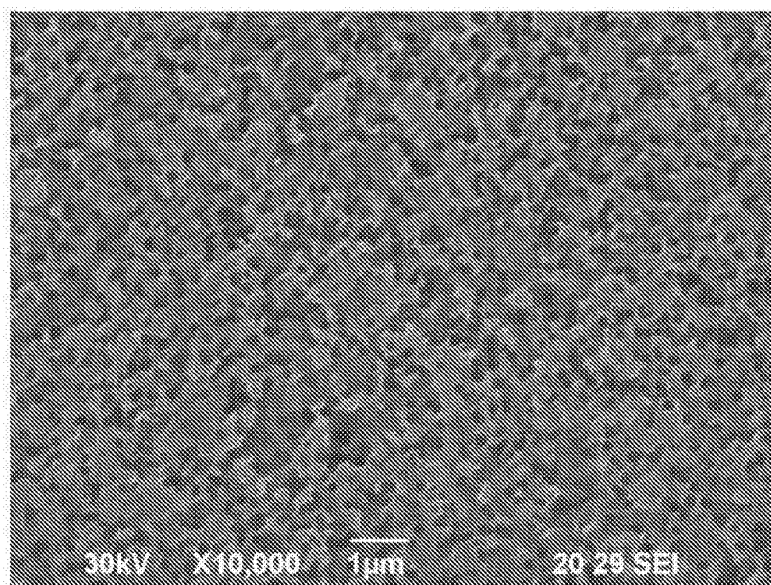


图3

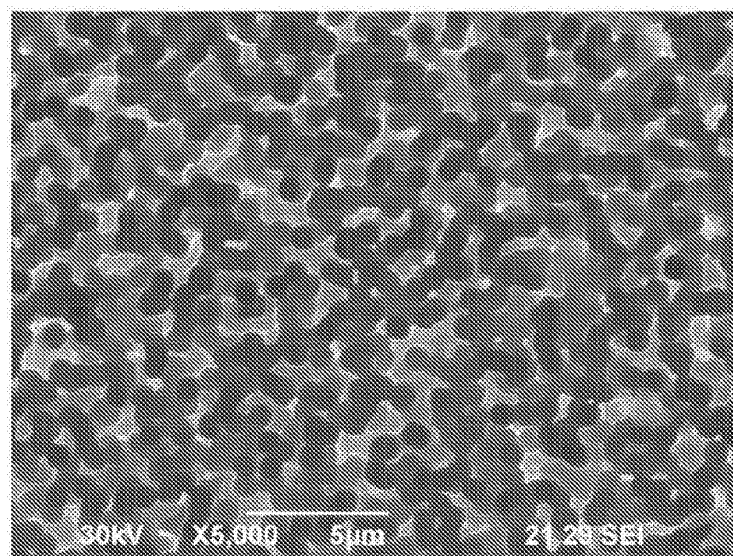


图4

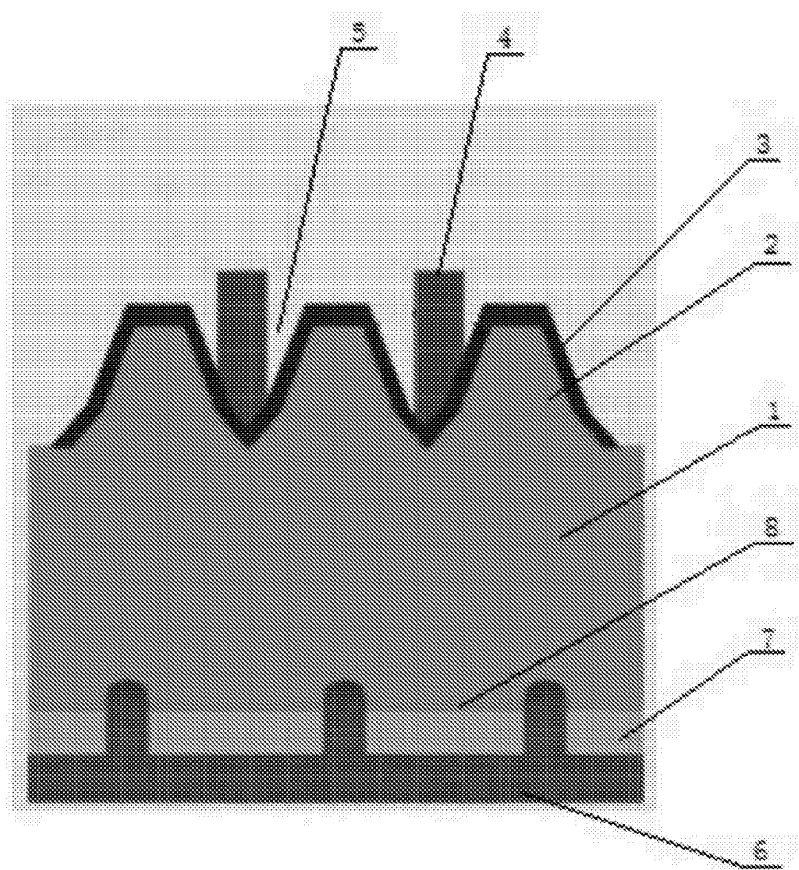


图5

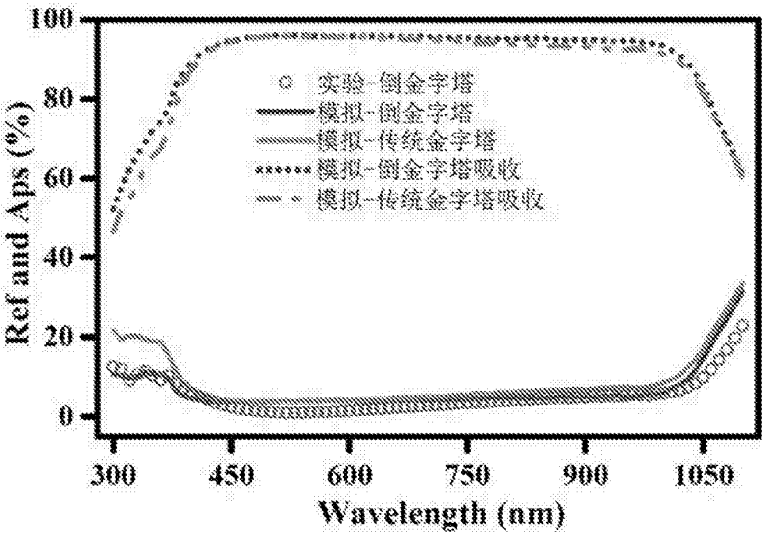


图6

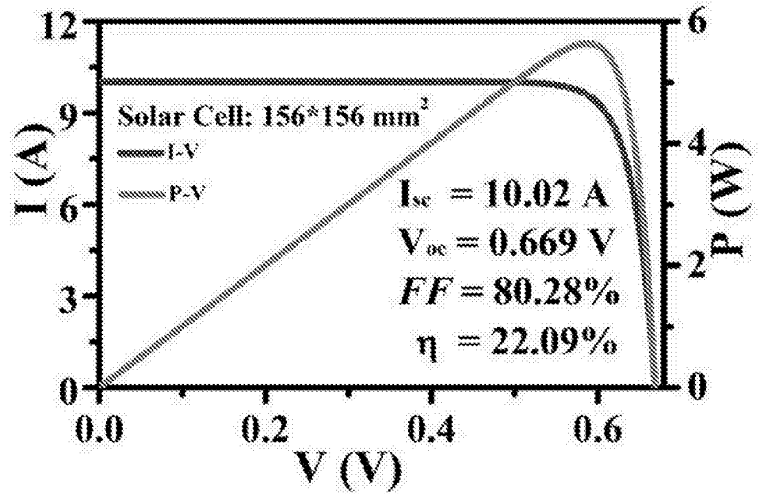


图7



Espacenet

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Monocrystalline silicon wafer with pyramid superposition structure and preparation method

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Abstract of CN111180538 (A)

The invention relates to the field of solar cells and discloses a monocrystalline silicon wafer with a pyramid superposition structure and a preparation method. After an original silicon wafer is cleaned through a solution a, anisotropic corrosion is carried out through a solution b to obtain a large pyramid textured surface, and then, secondary texturing is carried out through a solution c, so that a small pyramid textured surface with a smaller size is formed on the original large pyramid textured surface, small pyramids are sequentially stacked on the surface of the large pyramid from top to bottom to form pyramid units; since the pyramid units cover the surface of the silicon wafer and are superposed, the monocrystalline silicon wafer not only has the advantages of good contact between the large pyramid and the conductive grid line and high welding tension, but also has the advantages of low reflectivity of the small pyramid and high short-circuit current. The textured surface of the monocrystalline silicon wafer is of a pyramid superposition structure with different sizes, so that the monocrystalline silicon wafer not only has the advantages of good contact between the large pyramid and the conductive grid line and high welding tension, but also has the advantages of low reflectivity of the small pyramid and high short-circuit current.



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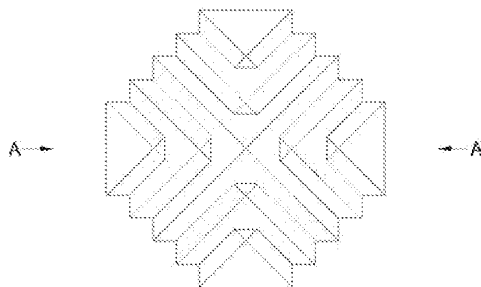
权利要求书1页 说明书5页 附图3页

### (54)发明名称

一种具有金字塔叠加结构的单晶硅片及制备方法

### (57)摘要

本发明涉及太阳能电池领域,公开了一种具有金字塔叠加结构的单晶硅片及制备方法,原硅片通过溶液a进行清洗后,在通过溶液b进行各向异性腐蚀,得到大金字塔绒面,再通过溶液c进行二次制绒后,使原有的大金字塔绒面上形成尺寸较小的小金字塔绒面,且大金字塔的表面从上到下依次叠加的有小金字塔,从而形成金字塔单元,因金字塔单元覆盖在硅片的表面,且是叠加的,所以该单晶硅片不仅具备了大金字塔与导电栅线接触好、焊接拉力高的优点,也具备了小金字塔反射率低、短路电流高的优点。本发明的单晶硅片绒面为不同大小的金字塔叠加结构,不仅具备了大金字塔与导电栅线接触好、焊接拉力高的优点,也具备了小金字塔反射率低、短路电流高的优点。



1. 一种具有金字塔叠加结构的单晶硅片,包括硅片,其特征在于:所述硅片制绒后其表面覆盖有金字塔单元。

2. 根据权利要求1所述的一种具有金字塔叠加结构的单晶硅片,其特征在于:所述金字塔单元包括大金塔,所述大金塔的表面从上到下依次叠加设有小金字塔。

3. 根据权利要求2所述的一种具有金字塔叠加结构的单晶硅片,其特征在于:所述小金字塔的底边长度小于大金塔的二分之一。

4. 根据权利要求1所述的一种具有金字塔叠加结构的单晶硅片,其特征在于:所述金字塔单元的底面积为 $1\sim 500$ 平方微米。

5. 根据权利要求4所述的一种具有金字塔叠加结构的单晶硅片,其特征在于:所述金字塔单元内包含的金字塔数量为 $5\sim 500$ 个。

6. 权利要求1~4任意一项所述的一种具有金字塔叠加结构的单晶硅片制备方法,其特征在于,包括以下步骤:

A、预清洗,去除原硅片表面沾污。使用氨水、氢氧化钠、氢氧化钾中的一种或几种,与双氧水混合得到溶液a,在溶液a中清洗原硅片,去除表面的颗粒物和有机沾污。

B、第一步制绒:将氢氧化钠或者氢氧化钾与制绒添加剂混合得到溶液b,在溶液b中对硅片进行各向异性腐蚀,得到尺寸较大的金字塔绒面结构,并形成大金塔绒面。

C、第二步制绒:将氢氧化钠或者氢氧化钾与制绒添加剂混合得到溶液c,并将步骤B制绒后的硅片放入溶液c中进行各向异性腐蚀,使原有的大金塔绒面被破坏,并在大金塔绒面上形成尺寸较小的小金字塔绒面,得到金字塔叠加的绒面结构。

D、碱洗:将氨水、氢氧化钠、氢氧化钾中的一种或几种,与双氧水混合成溶液d,在溶液d中清洗制绒硅片,去除制绒硅片表面的残留物。

## 一种具有金字塔叠加结构的单晶硅片及制备方法

### 技术领域

[0001] 本发明涉及太阳能电池领域,具体是指一种具有金字塔叠加结构的单晶硅片及制备方法。

### 背景技术

[0002] 单晶硅太阳能电池的制造过程中,通过槽式湿法制绒可以在硅片表面形成金字塔形貌的陷光结构,太阳光在金字塔表面发生二次反射,从而增加硅片对光的吸收率,提高太阳能电池的电流密度和光电转换效率。这种有陷光作用的绒面是利用硅片在碱液中的各向异性腐蚀形成的,硅片表面的晶面指数为(100),在含有制绒添加剂的碱液中发生各向异性化学反应时,晶面指数为(100)的表面逐渐消失,出现由晶面指数为(111)的表面组成的金字塔形貌。

[0003] 常规的单晶硅片绒面结构为大小不一的金字塔紧密排列,布满整个硅片表面,金字塔底边长度一般为0.2-20 $\mu\text{m}$ 。不同金字塔大小的绒面具有不同的光学特性和电学特性,一般而言,金字塔尺寸大的硅片对光线的反射率较高,做成的电池片的短路电流( $I_{sc}$ )较小;相反地,金字塔尺寸小的硅片对光线的反射率较低,做成的电池片的短路电流较高。但是金字塔尺寸小的硅片存在其它问题,例如丝网印刷导电栅线时,小金字塔绒面与导电栅线的接触不充分,增大了接触电阻,此外降低了栅线的焊接拉力。

### 发明内容

[0004] 基于以上技术问题,本发明提供了一种具有金字塔叠加结构的单晶硅片及制备方法。本发明的单晶硅片绒面为不同大小的金字塔叠加结构,不仅具备了大金字塔与导电栅线接触好、焊接拉力高的优点,也具备了小金字塔反射率低、短路电流高的优点。

[0005] 为解决以上技术问题,本发明采用的技术方案如下:

[0006] 一种具有金字塔叠加结构的单晶硅片,包括硅片,硅片制绒后其表面覆盖有金字塔单元。

[0007] 作为一种优选的方式,金字塔单元包括大金塔,大金塔的表面从上到下依次叠加设有小金塔。

[0008] 作为一种优选的方式,小金塔的底边长度小于大金塔的二分之一。

[0009] 作为一种优选的方式,金字塔单元的底面积为1~500平方微米。

[0010] 作为一种优选的方式,金字塔单元内包含的金字塔数量为5~500个。

[0011] 上述一种具有金字塔叠加结构的单晶硅片制备方法,其特征在于,包括以下步骤:

[0012] A、预清洗,去除原硅片表面沾污。使用氨水、氢氧化钠、氢氧化钾中的一种或几种,与双氧水混合得到溶液a,在溶液a中清洗原硅片,去除表面的颗粒物和有机沾污。

[0013] B、第一步制绒:将氢氧化钠或者氢氧化钾与制绒添加剂混合得到溶液b,在溶液b中对硅片进行各向异性腐蚀,得到尺寸较大的金字塔绒面结构,并形成大金塔绒面。

[0014] C、第二步制绒:将氢氧化钠或者氢氧化钾与制绒添加剂混合得到溶液c,并将步骤

B制绒后的单晶硅片放入溶液C中进行各向异性腐蚀,使原有的大金字塔绒面被破坏,并在大金字塔绒面上形成尺寸较小的小金字塔绒面,得到金字塔叠加的绒面结构。

[0015] D、碱洗:将氨水、氢氧化钠、氢氧化钾中的一种或几种,与双氧水混合成溶液d,在溶液d中清洗制绒单晶硅片,去除制绒单晶硅片表面的残留物。

[0016] 在本发明中,原硅片通过溶液a进行清洗后,在通过溶液b进行各向异性腐蚀,得到大金字塔绒面,再通过溶液c进行二次制绒后,使原有的大金字塔绒面上形成尺寸较小的小金字塔绒面,且大金字塔的表面从上到下依次叠加的有小金字塔,从而形成金字塔单元,因金字塔单元覆盖在硅片的表面,且是叠加的,所以该单晶硅片不仅具备了大金字塔与导电栅线接触好、焊接拉力高的优点,也具备了小金字塔反射率低、短路电流高的优点,且制造成电池片后,该电池片的转换效率高,焊接可靠性更好。

[0017] 本发明的有益效果如下:

[0018] (1) 本发明提供的方法制备的单晶硅片绒面为不同高度的金字塔叠加的结构,同时具备了大金字塔与导电栅线接触好、焊接拉力高的优点,以及小金字塔反射率低、短路电流高的优点。使用具有不同尺寸叠加的金字塔绒面的单晶硅片制造的电池片,与使用常规大绒面或小绒面硅片制造的电池片相比,转换效率有所提升,而且焊接可靠性更好。

[0019] (2) 本发明将氨水、氢氧化钠、氢氧化钾中的一种或几种,与双氧水混合成溶液d,在溶液d中清洗制绒硅片,可去除制绒硅片表面的反应产物和有机物残留。

#### 附图说明

[0020] 图1是本发明的SEM图;

[0021] 图2是将图1放大后的SEM图;

[0022] 图3是金字塔单元的结构示意图;

[0023] 图4是图3中A-A的剖面简图;

[0024] 图5是将图3拆开后的结构示意图;

[0025] 图6是本发明与导电栅线的接触示意图;

[0026] 图7是本发明的反射率曲线图。

#### 具体实施方式

[0027] 为了本技术领域的人员更好的理解本发明,下面结合附图和以下实施例对本发明作进一步详细描述。

[0028] 实施例1:

[0029] 参考图1~6,一种具有金字塔叠加结构的单晶硅片,包括硅片,硅片制绒后其表面覆盖有金字塔单元。

[0030] 作为一种优选的方式,金字塔单元包括大金塔,大金字塔的表面从上到下依次叠加设有小金字塔。

[0031] 作为一种优选的方式,小金字塔的底边长度小于大金字塔的二分之一。

[0032] 作为一种优选的方式,金字塔单元的底面积为1~500平方微米。

[0033] 作为一种优选的方式,金字塔单元内包含的金字塔数量为5~500个。

[0034] 上述一种具有金字塔叠加结构的单晶硅片制备方法,其特征在于,包括以下步骤:

[0035] A、预清洗,去除原硅片表面沾污。使用氨水、氢氧化钠、氢氧化钾中的一种或几种,与双氧水混合得到溶液a,在溶液a中清洗原硅片,去除表面的颗粒物和有机沾污。

[0036] B、第一步制绒:将氢氧化钠或者氢氧化钾与制绒添加剂混合得到溶液b,在溶液b中对硅片进行各向异性腐蚀,得到尺寸较大的金字塔绒面结构,并形成大金字塔绒面。

[0037] C、第二步制绒:将氢氧化钠或者氢氧化钾与制绒添加剂混合得到溶液c,并将步骤B制绒后的硅片放入溶液C中进行各向异性腐蚀,使原有的大金字塔绒面被破坏,并在大金字塔绒面上形成尺寸较小的小金字塔绒面,得到金字塔叠加的绒面结构。

[0038] D、碱洗:将氨水、氢氧化钠、氢氧化钾中的一种或几种,与双氧水混合成溶液d,在溶液d中清洗制绒硅片,去除制绒硅片表面的反应产物和有机物残留。

[0039] 在本实施例中,原硅片通过溶液a进行清洗后,在通过溶液b进行各向异性腐蚀,得到大金字塔绒面,再通过溶液c进行二次制绒后,使原有的大金字塔绒面上形成尺寸较小的小金字塔绒面,且大金字塔的表面从上到下依次叠加的有小金字塔,从而形成金字塔单元,因金字塔单元覆盖在硅片的表面,且是叠加的,所以该单晶硅片不仅具备了大金字塔与导电栅线接触好、焊接拉力高的优点,也具备了小金字塔反射率低、短路电流高的优点,且制造成电池片后,该电池片的转换效率高,焊接可靠性更好。

[0040] 具体的,大金字塔、小金字塔分别有四个面,且每个面都由单晶硅的(111)晶面组成。

[0041] 具体的,参考图6,其中导电栅线由大小不一的金属颗粒组成。因金字塔单元之间的沟壑较大,所以金属颗粒与金字塔的接触更充分,接触电阻小,同时导电栅线与绒面的结合可使焊接拉力更高。

[0042] 具体的,大金字塔的底边长度为10微米,则小金字塔的底边长度小于5微米。

[0043] 实施例2:

[0044] 参考图1~6,在本实施例中,可选但不限制于使用日本林纯HPC的制绒添加剂制备金字塔叠加结构的绒面,具体步骤如下:

[0045] (1) 预清洗

[0046] 在氨水与双氧水的混合溶液中清洗原硅片,溶液中氨水的质量浓度为3%,双氧水的质量浓度为3%,温度为65℃,清洗时间为5min。清洗结束后在常温纯水中漂洗硅片3min。

[0047] (2) 第一步制绒

[0048] 使用日本林纯HPC的制绒添加剂,溶液中各组分的质量浓度:氢氧化钾为7.5%,TK81为4%,TT72C13为0.6%,温度为85℃,时间为15min。制绒结束后在常温纯水中漂洗硅片3min。

[0049] (3) 第二步制绒

[0050] 使用日本林纯HPC的制绒添加剂,溶液中各组分的质量浓度:氢氧化钾为3.5%,TK81为8.5%,TT72C13为0.9%,温度为75℃,时间为15min。制绒结束后在常温纯水中漂洗硅片3min。

[0051] (4) 碱洗

[0052] 在氨水与双氧水的混合溶液中清洗制绒硅片,溶液中氨水的质量浓度为3%,双氧水的质量浓度为3%,温度为65℃,清洗时间为5min。清洗结束后在常温纯水中漂洗硅片3min。

[0053] (5) 化学抛光CP (Chemical polishing)

[0054] 对金字塔的棱角和沟壑进行圆滑处理,使用49%的氢氟酸和60%的硝酸,氢氟酸与硝酸的体积比为1:100,温度为25℃,时间为2min。CP结束后在常温纯水中漂洗硅片3min。

[0055] (6) 酸洗

[0056] 在盐酸与双氧水的混合溶液中清洗制绒硅片,溶液中盐酸的质量浓度为3%,双氧水的质量浓度为3%,温度为65℃,清洗时间为5min。清洗结束后在常温纯水中漂洗硅片3min。

[0057] (7) 去氧化层

[0058] 在质量浓度为5%的氢氟酸溶液中清洗制绒硅片,去除硅片表面的氧化层,温度为25℃,时间为2min。CP结束后在常温纯水中漂洗硅片2min。

[0059] (8) 慢提拉

[0060] 在60℃热水中清洗制绒硅片1min,然后将硅片缓慢提拉出水,提拉速度为5mm/s,硅片表面没有水滴残留。

[0061] (9) 烘干

[0062] 使用加热后的过滤空气吹干硅片,温度为50℃,时间为10min,烘干后得到表面洁净的制绒硅片,可以进行下一步CVD镀膜工艺。

[0063] 本实施例中的单晶硅片不仅具备了大金字塔与导电栅线接触好、焊接拉力高的优点,也具备了小金字塔反射率低、短路电流高的优点,且制造成电池片后,该电池片的转换效率高,焊接可靠性更好。

[0064] 本实施例的其他部分与实施例1相同,这里就不再赘述。

[0065] 实施例3:

[0066] 参考图1~6,在本实施例中,可选但不限制于使用德国ICB的制绒添加剂制备金字塔叠加结构的绒面,具体步骤如下:

[0067] (1) 预清洗

[0068] 在氢氧化钾与双氧水的混合溶液中清洗原硅片,溶液中氢氧化钾的质量浓度为1.5%,双氧水的质量浓度为3%,温度为65℃,清洗时间为5min。清洗结束后在常温纯水中漂洗硅片3min。

[0069] (2) 第一步制绒

[0070] 使用德国ICB的制绒添加剂,溶液中各组分的质量浓度:氢氧化钾为4.5%,ICB Ultra M为0.8%,温度为85℃,时间为10min。制绒结束后在常温纯水中漂洗硅片3min。

[0071] (3) 第二步制绒

[0072] 使用德国ICB的制绒添加剂,溶液中各组分的质量浓度:氢氧化钾为2%,ICB V3为0.5%,温度为80℃,时间为10min。制绒结束后在常温纯水中漂洗硅片3min。

[0073] (4) 碱洗

[0074] 在氢氧化钾与双氧水的混合溶液中清洗制绒硅片,溶液中氢氧化钾的质量浓度为1.5%,双氧水的质量浓度为3%,温度为65℃,清洗时间为5min。清洗结束后在常温纯水中漂洗硅片3min。

[0075] (5) 化学抛光CP (Chemical polishing)

[0076] 对金字塔的棱角和沟壑进行圆滑处理,使用臭氧和氢氟酸的混合溶液,臭氧浓度

为30ppm,氢氟酸的质量浓度为1%,温度为25℃,时间为3min。CP结束后在常温纯水中漂洗硅片3min。

[0077] (6) 酸洗

[0078] 在盐酸与双氧水的混合溶液中清洗制绒硅片,溶液中盐酸的质量浓度为3%,双氧水的质量浓度为3%,温度为65℃,清洗时间为5min。清洗结束后在常温纯水中漂洗硅片3min。

[0079] (7) 去氧化层

[0080] 在质量浓度为5%的氢氟酸溶液中清洗制绒硅片,去除硅片表面的氧化层,温度为25℃,时间为2min。CP结束后在常温纯水中漂洗硅片2min。

[0081] (8) 慢提拉

[0082] 在60℃热水中清洗制绒硅片1min,然后将硅片缓慢提拉出水,提拉速度为5mm/s,硅片表面没有水滴残留。

[0083] (9) 烘干

[0084] 使用加热后的过滤空气吹干硅片,温度为50℃,时间为10min,烘干后得到表面洁净的制绒硅片,可以进行下一步CVD镀膜工序。

[0085] 本实施例中的单晶硅片不仅具备了大金字塔与导电栅线接触好、焊接拉力高的优点,也具备了小金字塔反射率低、短路电流高的优点,且制造成电池片后,该电池片的转换效率高,焊接可靠性更好。

[0086] 本实施例的其他部分与实施例1相同,这里就不再赘述。

[0087] 如上即为本发明的实施例。上述实施例以及实施例中的具体参数仅是为了清楚表述本发明的验证过程,并非用以限制本发明的专利保护范围,本发明的专利保护范围仍然以其权利要求书为准,凡是运用本发明的说明书及附图内容所作的等同结构变化,同理均应包含在本发明的保护范围内。

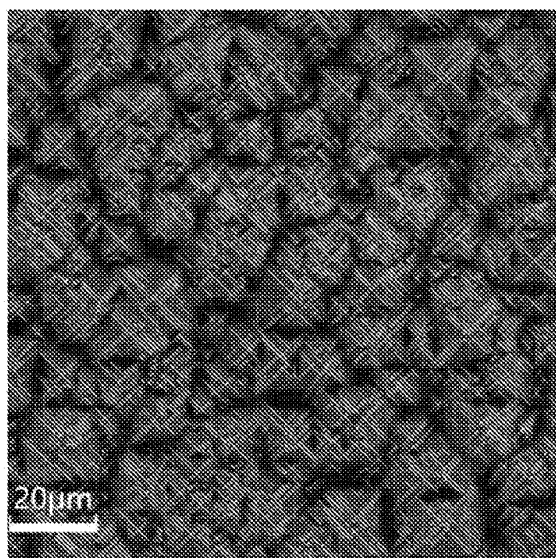


图1

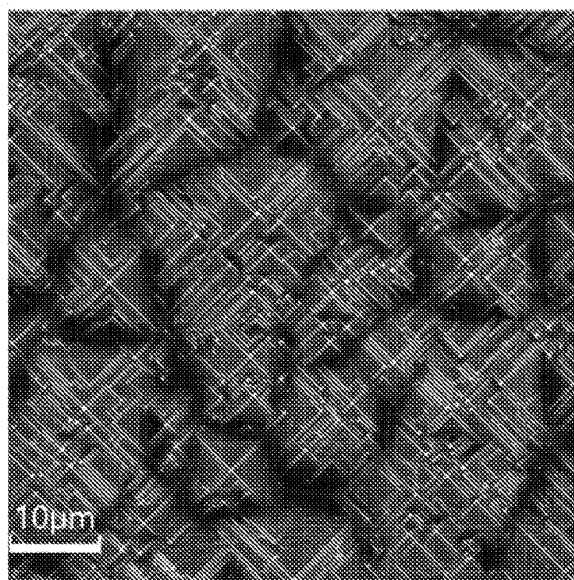


图2

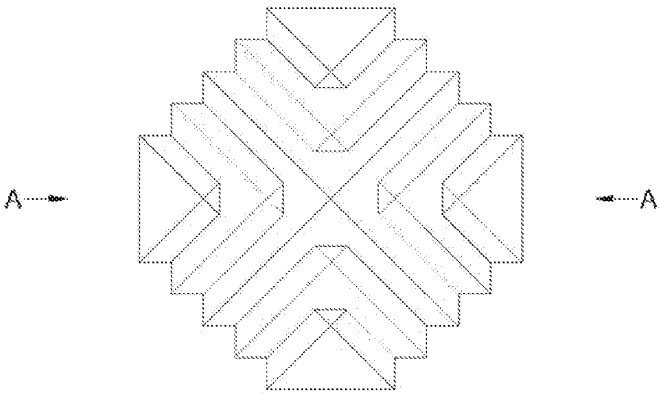


图3

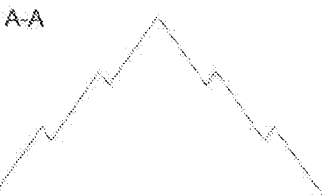


图4

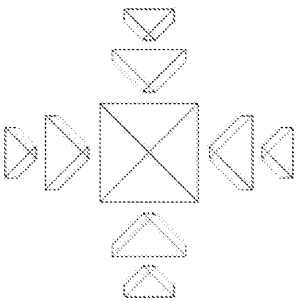


图5

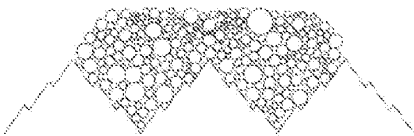


图6

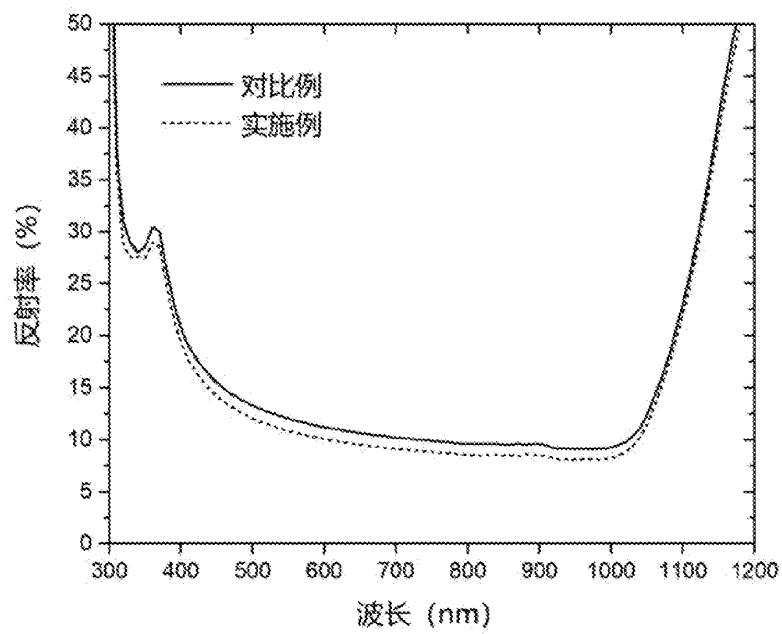


图7



Espacenet

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## NITRIDE SEMICONDUCTOR LIGHT-RECEIVING DEVICES AND MANUFACTURING METHOD THEREOF

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**Application number:** KR20170155599 20171121 Global Dossier

**Priority number(s):** KR20170155599 20171121

## Abstract of KR20190058017 (A)

The present invention relates to a nitride-based semiconductor light receiving element and a manufacturing method thereof. The nitride-based semiconductor light receiving element comprises: a substrate; a first semiconductor layer formed on the substrate; an absorption layer formed on the first semiconductor layer; and a second semiconductor layer formed on the absorption layer. One surface of the second semiconductor layer includes a concave-convex structure.



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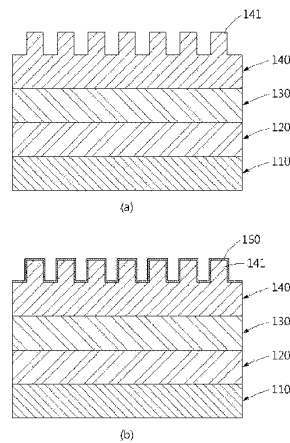
진체 청구항 수 : 총 17 항

(54) 발명의 명칭 질화물계 반도체 수광소자 및 이의 제조방법

(57) 요약

본 발명은, 질화물계 반도체 수광소자 및 이의 제조방법에 관한 것으로, 기판; 상기 기판 상에 형성된 제1 반도체층; 상기 제1 반도체층 상에 형성된 흡수층; 및 상기 흡수층 상에 형성된 제2 반도체층; 을 포함하고, 상기 제2 반도체층의 일면은, 요철 구조를 포함하는 것인, 질화물계 반도체 수광소자에 관한 것이다.

도면 - 도1



(52) CPC특허분류

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*H01L 31/18* (2013.01)

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명세서

청구범위

**청구항 1**

기관;

상기 기관 상에 형성된 제1 반도체층;

상기 제1 반도체층 상에 형성된 흡수층; 및

상기 흡수층 상에 형성된 제2 반도체층;

을 포함하고,

상기 제2 반도체층의 일면은, 요철 구조를 포함하는 것인, 질화물계 반도체 수광소자.

**청구항 2**

제1항에 있어서,

상기 질화물계 반도체 수광소자는, 수평형 수광 구조이며,

상기 제1 반도체층은, n-형 질화물계 반도체를 포함하고,

상기 제2 반도체층은, p-형 질화물계 반도체를 포함하는 것인, 질화물계 반도체 수광소자.

**청구항 3**

제1항에 있어서,

상기 질화물계 반도체 수광소자는, 수직형 수광 구조이며,

상기 제1 반도체층은, p-형 질화물계 반도체를 포함하고,

상기 제2 반도체층은, n-형 질화물계 반도체를 포함하는 것인, 질화물계 반도체 수광소자.

**청구항 4**

제1항에 있어서,

상기 제2 반도체층은, 수광면인 것인, 질화물계 반도체 수광소자.

**청구항 5**

제1항에 있어서,

상기 요철 구조는, 반원, 원뿔, 다각뿔, 니들, 원기둥 및 다각 기둥으로 이루어진 군에서 선택된 1종 이상의 구조체를 포함하는 것인, 질화물계 반도체 수광소자.

**청구항 6**

제1항에 있어서,

상기 요철 구조는,  $0.01\ \mu\text{m}$  내지  $10\ \mu\text{m}$ 의 높이를 갖는 것인, 질화물계 반도체 수광소자.

#### 청구항 7

제1항에 있어서,

상기 요철 구조는,  $0.01\ \mu\text{m}$  내지  $10\ \mu\text{m}$  간격으로 배열된 것인, 질화물계 반도체 수광소자.

#### 청구항 8

제1항에 있어서,

상기 질화물계 반도체 수광소자는, 90 % 이상의 광투과도를 갖는 것인, 질화물계 반도체 수광소자.

#### 청구항 9

제1항에 있어서,

상기 질화물계 반도체 수광소자는, 12 % 이상의 광흡수효율을 갖는 것인, 질화물계 반도체 수광소자.

#### 청구항 10

제1항에 있어서,

상기 요철 구조 상에 형성된 반사방지층;을 더 포함하는 것인, 질화물계 반도체 수광소자.

#### 청구항 11

제10항에 있어서,

상기 반사방지층은,  $\text{SiO}_2$ ,  $\text{Si}_x\text{N}_y$ ,  $\text{SiO}_x\text{N}_y$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{AlN}$  및  $\text{Ag}$ 로 이루어진 군에서 선택된 1종 이상을 포함하는 것인, 질화물계 반도체 수광소자.

#### 청구항 12

제10항에 있어서,

상기 반사방지층은,  $0.01\ \mu\text{m}$  내지  $1\ \mu\text{m}$  두께를 갖는 것인, 질화물계 반도체 수광소자.

#### 청구항 13

제2항에 있어서,

상기 질화물계 반도체는,  $\text{GaN}$ ,  $\text{AlN}$  및  $\text{Ga}(x)\text{Al}(1-x)\text{N}$  계 반도체로 이루어진 군에서 선택된 1종 이상을 포함하는 것인, 질화물계 반도체 수광소자.

#### 청구항 14

기판 상에 제1 반도체층을 형성하는 단계;

상기 제1 반도체층 상에 흡수층을 형성하는 단계;  
 상기 흡수층 상에 제2 반도체층을 형성하는 단계; 및  
 상기 제2 반도체층의 적어도 일면에 요철 구조를 형성하는 단계;  
 를 포함하는,  
 질화물계 반도체 수광소자의 제조방법.

#### 청구항 15

제14항에 있어서,  
 상기 요철 구조를 형성하는 단계는,  
 상기 제2 반도체층 상에 마스크층을 형성하는 단계; 및  
 상기 마스크층 내에 개방된 제2 반도체층 상에서 구조체를 성장시키는 단계;  
 를 포함하는, 질화물계 반도체 수광소자의 제조방법.

#### 청구항 16

제14항에 있어서,  
 상기 요철 구조를 형성하는 단계는,  
 상기 제2 반도체층 상에 마스크층을 형성하는 단계; 및  
 상기 마스크층 내에 개방된 제2 반도체층을 식각하는 단계;  
 를 포함하는, 질화물계 반도체 수광소자의 제조방법.

#### 청구항 17

제14항에 있어서,  
 상기 요철 구조가 형성된 제2 반도체층 상에 반사방지층을 형성하는 단계;  
 를 더 포함하는 것인, 질화물계 반도체 수광소자의 제조방법.

#### 발명의 설명

#### 기술분야

[0001] 본 발명은, 질화물계 반도체 수광소자 및 이의 제조방법에 관한 것이다.

#### 배경기술

- [0002] 수광소자는, 광을 수광하여 동작하는 반도체 소자이며, 반도체에서 발생하는 광전 효과를 통해 전자기적 에너지를 전기적인 에너지로 변환한다. 이러한 수광 소자는 다양한 형태로 구현되며, 광검출기, 태양전지 등이 있다.
- [0003] 일반적인 수광소자의 경우에는 에너지 효율을 극대화하고, 수광 효율을 증가시키기 위해서 높은 전기 전도도와 가시광뿐만 아니라 자외선 영역에서 우수한 투과도 특성을 지닌 투명전극이 적용되고, 빛을 받는 면적(absorption region)을 가능한 크게하는 방식이 적용되고 있다. 이러한 수광면적이 넓어짐에 따라 반도체 물질에 존재하는 결함(defect)에 의해 전류 누설이 발생하게 되는 문제점이 있다.

### 발명의 내용

#### 해결하려는 과제

- [0004] 본 발명은 진술한 바와 같은 문제점을 해결하기 위한 것으로, 일정한 흡수영역에서 최대한 많은 빛을 검출하여 수광효율을 향상시키고, 전기적 특성이 향상된 질화물 반도체계 수광소자를 제공하는 것이다.
- [0005] 본 발명은, 본 발명에 의한 질화물 반도체계 수광소자의 제조방법을 제공하는 것이다.
- [0006] 본 발명이 해결하고자 하는 과제는 이상에서 언급한 과제로 제한되지 않으며, 언급되지 않은 또 다른 과제들은 아래의 기재로부터 통상의 기술자에게 명확하게 이해될 수 있을 것이다.

#### 과제의 해결 수단

- [0007] 본 발명의 하나의 양상은,
- [0008] 기판; 상기 기판 상에 형성된 제1 반도체층; 상기 제1 반도체층 상에 형성된 흡수층; 및 상기 흡수층 상에 형성된 제2 반도체층;을 포함하고, 상기 제2 반도체층의 일면은, 요철 구조를 포함하는 것인, 질화물계 반도체 수광소자에 관한 것이다.
- [0009] 본 발명의 일 실시예에 따라, 상기 질화물계 반도체 수광소자는, 수평형 수광 구조이며, 상기 제1 반도체층은, n-형 질화물계 반도체를 포함하고, 상기 제2 반도체층은, p-형 질화물계 반도체를 포함할 수 있다.
- [0010] 본 발명의 일 실시예에 따라, 상기 질화물계 반도체 수광소자는, 수직형 수광 구조이며, 상기 제1 반도체층은, p-형 질화물계 반도체를 포함하고, 상기 제2 반도체층은, n-형 질화물계 반도체를 포함할 수 있다.
- [0011] 본 발명의 일 실시예에 따라, 상기 요철 구조는, 반원, 원뿔, 다각뿔, 니들, 원기둥 및 다각 기둥으로 이루어진 군에서 선택된 1종 이상의 구조체를 포함할 수 있다.
- [0012] 본 발명의 일 실시예에 따라, 상기 요철 구조는, 0.01  $\mu\text{m}$  내지 10  $\mu\text{m}$ 의 높이를 갖는 것일 수 있다.
- [0013] 본 발명의 일 실시예에 따라, 상기 요철 구조는, 0.01  $\mu\text{m}$  내지 10  $\mu\text{m}$ 의 간격으로 배열될 수 있다.
- [0014] 본 발명의 일 실시예에 따라, 상기 질화물계 반도체 수광소자는, 90 % 이상의 광투과도를 갖는 것일 수 있다.
- [0015] 본 발명의 일 실시예에 따라, 상기 질화물계 반도체 수광소자는, 12 % 이상의 광흡수효율을 갖는 것일 수 있다.
- [0016] 본 발명의 일 실시예에 따라, 상기 요철 구조 상에 형성된 반사방지층;을 더 포함할 수 있다.
- [0017] 본 발명의 일 실시예에 따라, 상기 반사방지층은,  $\text{SiO}_2$ ,  $\text{Si}_x\text{N}_y$ ,  $\text{SiO}_x\text{N}_y$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{AlN}$  및  $\text{Ag}$ 로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다.
- [0018] 본 발명의 일 실시예에 따라, 상기 반사방지층은, 0.01  $\mu\text{m}$  내지 1  $\mu\text{m}$  두께를 갖는 것일 수 있다.
- [0019] 본 발명의 일 실시예에 따라, 상기 질화물계 반도체는,  $\text{GaN}$ ,  $\text{AlN}$  및  $\text{Ga}(x)\text{Al}(1-x)\text{N}$  계 반도체로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다.
- [0020] 본 발명의 다른 양상은, 기판 상에 제1 반도체층을 형성하는 단계; 상기 제1 반도체층 상에 흡수층을 형성하는 단계; 상기 흡수층 상에 제2 반도체층을 형성하는 단계; 및 상기 제2 반도체층의 적어도 일면에 요철 구조를 형성하는 단계;를 포함하는, 질화물계 반도체 수광소자의 제조방법에 관한 것이다.
- [0021] 본 발명의 일 실시예에 따라, 상기 요철 구조를 형성하는 단계는, 상기 제2 반도체층 상에 마스크층을 형성하는 단계; 및 상기 마스크층 내에 개방된 제2 반도체층 상에서 구조체를 성장시키는 단계;를 포함할 수 있다.
- [0022] 본 발명의 일 실시예에 따라, 상기 요철 구조를 형성하는 단계는, 상기 제2 반도체층 상에 마스크층을 형성하는 단계; 및 상기 마스크층 내에 개방된 제2 반도체층을 식각하는 단계;를 포함할 수 있다.
- [0023] 본 발명의 일 실시예에 따라, 상기 요철 구조가 형성된 제2 반도체층 상에 반사방지층을 형성하는 단계;를 더 포함할 수 있다.

#### 발명의 효과

- [0024] 본 발명은, 반도체층 일면에 요철구조를 형성하여, 우수한 투과도를 가지면서, 전류 밀도 및 수광 효율이 향상

된 질화물 반도체계 수광소자를 제공할 수 있다.

#### 도면의 간단한 설명

- [0025] 도 1은, 본 발명의 일 실시예에 따라, 본 발명에 의한 질화물계 반도체 수광 소자의 단면을 예시적으로 나타낸 것이다.
- 도 2는, 본 발명의 일 실시예에 따라, 본 발명에 의한 요철구조의 단면을 예시적으로 나타낸 것이다.
- 도 3은, 본 발명의 일 실시예에 따라, 본 발명에 의한 요철구조의 상부면을 예시적으로 나타낸 것이다.
- 도 4는, 본 발명의 일 실시예에 따라, 본 발명에 의한 질화물계 반도체 수광소자의 제조방법의 공정을 예시적으로 나타낸 것이다.
- 도 5는, 본 발명의 일 실시예에 따라, 본 발명의 실시예의 표면 요철의 형태의 변화에 따른 FDTD 시뮬레이션 결과를 나타낸 것이다.
- 도 6은, 본 발명의 일 실시예에 따라, 본 발명의 실시예의 반사방지층의 두께의 변화에 따른 FDTD 시뮬레이션 결과를 나타낸 것이다.

#### 발명을 실시하기 위한 구체적인 내용

- [0026] 이하 첨부된 도면을 참조하여 본 발명의 실시예들을 상세히 설명한다. 본 발명을 설명함에 있어서, 관련된 공지 기능 또는 구성에 대한 구체적인 설명이 본 발명의 요지를 불필요하게 흐릴 수 있다고 판단되는 경우에는 그 상세한 설명을 생략할 것이다. 또한, 본 명세서에서 사용되는 용어(terminology)들은 본 발명의 바람직한 실시예를 적절히 표현하기 위해 사용된 용어들로서, 이는 사용자, 운용자의 의도 또는 본 발명이 속하는 분야의 관례 등에 따라 달라질 수 있다. 따라서, 본 용어들에 대한 정의는 본 명세서 전반에 걸친 내용을 토대로 내려져야 할 것이다. 각 도면에 제시된 동일한 참조 부호는 동일한 부재를 나타낸다.
- [0027] 본 발명은, 질화물계 반도체 수광소자에 관한 것으로, 본 발명의 일 실시예에 따라, 상기 수광소자는, 수광면 부분에 반도체 요철구조를 형성하며, 수광효율을 향상시킬 수 있다.
- [0028] 본 발명의 일 실시예에 따라, 상기 수광소자는, 기판(110); 제1 반도체층(120); 광흡수층(130); 및 제2 반도체층(140);을 포함할 수 있고, 제2 반도체층(140) 상에 반사방지층(150)을 더 포함할 수 있다.
- [0029] 본 발명의 일 실시예에 따라, 기판(110)은, 수광 소자의 구조에 따라 선택될 수 있으며, 수평형 수광 구조일 경우에, 사파이어 ( $Al_2O_3$ ), Si, SiC, GaN 및 AlN으로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다. 또한, 수직형 수광 구조일 경우에, 투명 전도성 기판(conductive substrate)이며, Co, Ir, Ta, Cr, Mn, Mo, Tc, W, Re, Fe, Sc, Ti, Ge, Sb, Al, Pt, Ni, Cu, Rh, Au, V, Nb, Ag, Pd, Zn, Ni, Si, Sn 및 Ru; 이들의 합금; 및 이들의 산화물; 로 이루어진 군에서 선택된 1종 이상을 포함하는 투명전극 기판일 수 있다. 예를 들어, 상기 산화물은, ZnO, ITO, ZITO, ZIO, GIO, ZTO, FTO, AZO, GZO 등일 수 있다.
- [0030] 본 발명의 일 실시예에 따라, 제1 반도체층(120)은, 기판(110) 상에 형성되고, 질화물계 반도체층이며, 수광 소자의 종류에 따라 선택될 수 있으며, 수평형 수광 구조일 경우에, n-형 질화물계 반도체층이고, 수직형 수광 구조일 경우에, p-형 질화물계 반도체층일 수 있다. 예를 들어, n-형 질화물계 반도체 및 p-형 질화물계 반도체는, 각각, GaN, GaNP, GaNAs, GaNSb, InGaN, GaInNP, GaInNAs, GaInNSb, AlN 및  $Ga(x)Al(1-x)N$  계 반도체(x는 유리수이다.)로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다.
- [0031] 본 발명의 일 예로, 제1 반도체층(120)은, 0.001  $\mu m$  내지 1  $\mu m$  두께로 형성될 수 있고, 바람직하게는 0.01  $\mu m$  내지 0.1  $\mu m$  일 수 있다.
- [0032] 본 발명의 일 실시예에 따라, 광흡수층(130)은, 광전변환층이며, 제1 반도체층(120) 상에 형성되고, i-형 질화물계 반도체층이며, 예를 들어, GaN, GaNP, GaNAs, GaNSb, InGaN, GaInNP, GaInNAs, GaInNSb, AlN 및  $Ga(x)Al(1-x)N$  계 반도체로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다.
- [0033] 본 발명의 일 예로, 광흡수층(130)은, 단일 또는 복수층으로 형성될 수 있으며, 상기 복수층은 동일하거나 또는 상이한 성장율의 i-형 질화물계 반도체를 포함할 수 있다.
- [0034] 본 발명의 일 실시예에 따라, 제2 반도체층(140)은, 광흡수층(130) 상에 형성되고, 수광소자의 수광면의 기능을 가진다. 제2 반도체층(140)은, 질화물계 반도체층이며, 수광 소자의 구조에 따라 선택될 수 있으며, 수평형 수

광 구조일 경우에, p-형 질화물계 반도체층이고, 수직형 수광 구조일 경우에, n-형 질화물계 반도체층일 수 있다. 예를 들어, n-형 질화물계 반도체 및 p-형 질화물계 반도체는, 각각, GaN, GaNP, GaNAs, GaNSb, InGaN, GaInNP, GaInNAs, GaInNSb, AlN 및  $Ga(x)Al(1-x)N$  계 반도체로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다.

- [0035] 본 발명의 일 예로, 제2 반도체층(120)은, 0.01  $\mu m$  내지 1  $\mu m$  두께로 형성될 수 있고, 바람직하게는 0.01  $\mu m$  내지 0.30  $\mu m$  일 수 있다.
- [0036] 본 발명의 일 실시예에 따라, 제2 반도체층(140)의 적어도 일면에 표면 요철구조(141)가 형성될 수 있다. 상기 요철구조는, 수광면의 기능을 갖는 제2 반도체층(140) 상에 형성되어 빛이 흡수되는 경로를 변화시키고, 흡수된 빛이 외부로 추출되지 않고, 광흡수층(130)에서 구속시켜 수광효율을 향상시킬 수 있다.
- [0037] 본 발명의 일 예로, 요철구조(141)는, 다양한 형상의 구조체를 포함할 수 있으며, 예를 들어, 반원, 원뿔, 다각뿔, 니들, 원기둥 및 다각 기둥으로 이루어진 군에서 선택된 1종 이상의 3차원 구조체를 포함할 수 있다. 예를 들어, 사각기둥, 육각기둥, 삼각뿔, 육각뿔(피라미드) 등일 수 있다.
- [0038] 예를 들어, 도 2를 참조하면, 도 2는 본 발명의 일 실시예에 따른, 요철구조의 단면을 예시적으로 나타낸 것으로, 도 2에서 (a) 사각기둥, (b) 반원, (c) 니들 및 (d) 육각기둥의 구조체가 형성될 수 있다. 또한, 도 3을 살펴보면, 도 3은, 본 발명에 의한 요철구조의 상부면을 나타낸 것으로, (a) 사각, (b) 원, (c) 육각형일 수 있다.
- [0039] 본 발명의 일 예로, 요철구조(141)는, 서로 간에 0.01  $\mu m$  내지 10  $\mu m$  간격으로 배열된 것일 수 있다. 상기 간격은, 하나의 구조체 밑면의 중심에서 이웃한 구조체 밑면의 중심 간의 거리(a)이다. 상기 간격은, 구조체들 간에 동일하거나 또는 상이할 수 있다.
- [0040] 본 발명의 일 예로, 요철구조(141)는, 랜덤 또는 규칙적으로 배열된 구조체를 포함할 수 있다. 예를 들어, 상기 구조체는, 원, 타원, 다각형, 중심점이 있는 원, 타원 및 다각형; 격자 및 라인 중 1종 이상의 형태로 배열될 수 있다.
- [0041] 본 발명의 일 예로, 요철구조(141)는, 0.01  $\mu m$  내지 10  $\mu m$  의 높이 및 0.01  $\mu m$  내지 10  $\mu m$  크기를 갖는 것일 수 있다. 상기 크기는, 구조체의 형태에 따라 밑면의 직경, 폭, 반경, 높이 등일 수 있다.
- [0042] 본 발명의 일 예로, 요철구조(141)는, 제2 반도체층(140)과 동일하거나 또는 상이한 질화물계 반도체 화합물을 포함할 수 있으며, 바람직하게는 제2 반도체층(140)과 동일한 질화물계 반도체 화합물을 포함할 수 있다.
- [0043] 본 발명의 일 예로, 제2 반도체층(140)은, 0.01  $\mu m$  내지 1  $\mu m$  두께로 형성될 수 있고, 바람직하게는 0.1  $\mu m$  내지 0.5  $\mu m$  일 수 있다.
- [0044] 본 발명의 일 실시예에 따라, 반사방지층(150)은, 제2 반도체층(140) 상의 적어도 일면의 적어도 일부분에 형성되며, 바람직하게는 제2 반도체층(140) 상에 요철구조(141)이 형성된 영역일 수 있으며, 예를 들어, 구조체의 표면 및 구조체들(141) 사이의 제2 반도체층(140)의 표면 상에 형성될 수 있다.
- [0045] 본 발명의 일 예로, 반사방지층(150)은,  $SiO_2$ ,  $Si_xN_y$ ,  $SiO_xN_y$ ,  $Al_2O_3$ ,  $TiO_2$ , AlN, Ag,  $ZrO_2$ ,  $HfO_2$ ,  $Ta_2O_5$  및 ZnO로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다.
- [0046] 본 발명의 일 예로, 반사방지층(150)은, 1000 nm 이하; 500 nm 이하; 1 nm 내지 200 nm의 두께를 갖는 것일 수 있다.
- [0047] 본 발명의 일 실시예에 따라, 질화물계 반도체 수광소자는, 소자 구동을 위해서 n-형 금속 전극 및 p-형 금속 전극을 더 포함할 수 있다(도면에 도시하지 않음). 상기 n-형 금속 전극 및 p-형 금속 전극은, 제1 반도체층 및 제2 반도체층 상에 형성될 수 있고, 수광소자의 구동을 위해서 적절하게 배치될 수 있다.
- [0048] 예를 들어, 상기 n-형 금속 전극층 및 p-형 금속 전극은, Co, Ir, Ta, Cr, Mn, Mo, Tc, W, Re, Fe, Sc, Ti, Sn, Ge, Sb, Al, Pt, Ni, Au, ITO 및 ZnO로 이루어진 군에서 선택된 1종 이상을 포함할 수 있다.
- [0049] 본 발명의 일 예로, 상기 질화물계 반도체 수광소자는, 90 % 또는 95 % 이상의 광투과도를 갖는 것일 수 있다.
- [0050] 본 발명의 일 예로, 상기 질화물계 반도체 수광소자는, 12 % 이상; 또는 15 % 이상의 광흡수효율을 갖는 것일 수 있다.

- [0051] 본 발명은, 본 발명에 의한 질화물계 반도체 수광소자의 제조방법에 관한 것으로, 본 발명의 일 실시예에 따라, 상기 제조방법은, 수광효율 및 전기적 특성이 우수한 수광소자를 제공할 수 있다.
- [0052] 도 4를 참조하여 설명하여, 도 4는, 본 발명의 일 실시예에 따라, 본 발명에 의한 질화물계 반도체 수광소자의 제조방법의 공정을 예시적으로 나타낸 것으로, 도 4에서 상기 제조방법은, 기판을 준비하는 단계(S210); 제1 반도체층을 형성하는 단계(S2210); 제1 반도체층 상에 흡수층을 형성하는 단계(S230); 제2 반도체층을 형성하는 단계(S240); 및 요철 구조를 형성하는 단계(S250); 를 포함하고, 반사방지층을 형성하는 단계(S260)를 더 포함할 수 있다.
- [0053] 본 발명의 일 실시예에 따라, 기판을 준비하는 단계(S210)는, 수광소자의 구조에 따라 적절한 기판을 준비하는 단계이다.
- [0054] 본 발명의 일 실시예에 따라, 제1 반도체층을 형성하는 단계(S210)는, 기판(110) 상에 제1 반도체층(120)을 형성하는 단계이다. 예를 들어, PVD(Physical Vapor Deposition), MOCVD(Metal-organic chemical vapour deposition), MBE(Molecular Beam Epitaxy), HVPE(Hydride Vapour Phase Epitaxy) 등을 이용할 수 있다.
- [0055] 본 발명의 일 실시예에 따라, 흡수층을 형성하는 단계(S230)는, 제1 반도체층(120) 상에 흡수층을 형성하는 단계이다. 예를 들어, PVD(Physical Vapor Deposition), MOCVD(Metal-organic chemical vapour deposition), MBE(Molecular Beam Epitaxy), HVPE(Hydride Vapour Phase Epitaxy) 등을 이용할 수 있다.
- [0056] 예를 들어, 흡수층을 형성하는 단계(S230)는, 500 °C 내지 1000 °C 온도에서 실시될 수 있다.
- [0057] 본 발명의 일 실시예에 따라, 제2 반도체층을 형성하는 단계(S240)는, 흡수층(130) 상에 제2 반도체층(140)을 형성하는 단계(S230)이다. 예를 들어, PVD(Physical Vapor Deposition), MOCVD(Metal-organic chemical vapour deposition), MBE(Molecular Beam Epitaxy), HVPE(Hydride Vapour Phase Epitaxy) 등을 이용할 수 있다.
- [0058] 본 발명의 일 실시예에 따라, 요철 구조를 형성하는 단계(S250)는, 제2 반도체층(140)의 적어도 일면의 적어도 일부분에 요철구조(141)를 형성하는 단계이다.
- [0059] 본 발명의 일 실시예에 따라, 요철 구조를 형성하는 단계(S250)는, 제2 반도체층 상에 마스크층을 형성하는 단계(S251a); 및 제2 반도체층 상에서 구조체를 성장시키는 단계(S252a); 를 포함할 수 있다.
- [0060] 본 발명의 일 예로, 제2 반도체층 상에 마스크층을 형성하는 단계(S251a)는, 제2 반도체층(140) 상의 적어도 일부분에 마스크층을 증착하는 단계이며, 상기 마스크층은, 요철구조의 형태, 배열 등에 따라 리소그래피 공정 등으로 패터닝될 수 있다. 예를 들어, 포토리소그래피, e-빔 리소그래피 등을 이용할 수 있다.
- [0061] 본 발명의 일 예로, 제2 반도체층 상에서 구조체를 성장시키는 단계(S252a)는, 상기 마스크층의 패터닝에 따라 개방된 제2 반도체층(140) 상에 구조체를 성장시켜 요철구조(141)를 형성하는 단계이다.
- [0062] 예를 들어, 구조체를 성장시키는 단계(S252a)는, PVD(Physical Vapor Deposition), MOCVD(Metal-organic chemical vapour deposition), MBE(Molecular Beam Epitaxy), HVPE(Hydride Vapour Phase Epitaxy) 등을 이용할 수 있다.
- [0063] 예를 들어, 구조체를 성장시키는 단계(S252a)는, 500 °C 내지 1000 °C 온도 에서 실시될 수 있다.
- [0064] 본 발명의 일 예로, 구조체를 성장시키는 단계(S252a) 이후에 마스크층을 제거하는 공정을 더 포함할 수 있다.
- [0065] 본 발명의 일 실시예에 따라, 요철 구조를 형성하는 단계(S250)는, 제2 반도체층 상에 마스크층을 형성하는 단계(S251b); 및 제2 반도체층을 식각하는 단계(S252b); 를 포함할 수 있다.
- [0066] 본 발명의 일 예로, 제2 반도체층 상에 마스크층을 형성하는 단계(S251b)는, 제2 반도체층(140) 상의 적어도 일부분에 마스크층을 증착하는 단계이며, 상기 마스크층은, 요철구조의 형태, 배열 등에 따라 리소그래피 공정 등으로 패터닝될 수 있다. 예를 들어, 포토리소그래피, e-빔 리소그래피 등을 이용할 수 있다.
- [0067] 본 발명의 일 예로, 제2 반도체층을 식각하는 단계(S252b)는, 상기 마스크층의 패터닝에 따라 개방된 제2 반도체층을 식각하여 요철구조를 형성하는 단계이다.
- [0068] 예를 들어, 상기 식각은, 습식 식각, 건식 식각 등을 이용할 수 있으며, 이온빔 FIB(Forced Ion Beam), Deep RIE 식각, 전기화학식각, 습식식각, 또는 건식식각으로 수행될 수 있다.
- [0069] 본 발명의 일 실시예에 따라, 반사방지층을 형성하는 단계(S260)는, 제2 반도체층의 요철구조가 형성된 면에 반

사방지층(150)을 증착하는 단계이다. 예를 들어, 스퍼터링, CVD, PECVD, PVD, HDPCVD, ALD 등의 증착, E-빔, 연증착 등을 이용할 수 있다.

[0070] 실시예

[0071] (1) FDTD 시뮬레이션을 이용하여 표면에 요철구조를 갖는 소자의 투과도 및 상대적인 흡수효율을 계산하여 표 1에 나타내었다.

[0072] 수평형 수광 소자: 사파이어 기판/n-GaN층/i-GaN 흡수층/p-GaN층

[0073] 반사방지층: SiO<sub>2</sub>

[0074] 두께:  $\lambda/4n$

[0075] 광원: 평면파,  $\lambda = 525 \text{ nm}$ ,  $\lambda_h = 50 \text{ nm}$ , Normal incident angle

표 1

[0076]

| 수광면 표면 구조   | 투과도(%) | 상대적 광흡수 효율(%) |
|-------------|--------|---------------|
| 평면          | 83.34  | 11.9          |
| 평면+반사방지막 코팅 | 99.49  | 12.5          |
| 표면 요철(육각기둥) | 99.29  | 42.3          |

[0077] 표 1을 살펴보면, FDTD 시뮬레이션의 결과에서, 수광면에 요철구조를 갖는 소자는 투과도 및 상대적인 광흡수율이 요철구조가 형성되지 않은 수광면(평면)을 갖는 소자에 비하여, 수광효율이 월등하게 향상된 것을 확인할 수 있다.

[0078] (2) FDTD 시뮬레이션을 이용하여 표면 요철의 형태에 따라 광흡수율(광원 파장: 360 nm)을 계산하여 도 5에 나타내었다.

[0079] (3) FDTD 시뮬레이션을 이용하여 표면 요철(육각기둥) 면에 반사방지층 84 nm, 168 nm, 336 nm 및 442 nm를 각각 증착하여 상대적인 광흡수율을 파장에 따라 계산하여 도 6에 나타내었다.

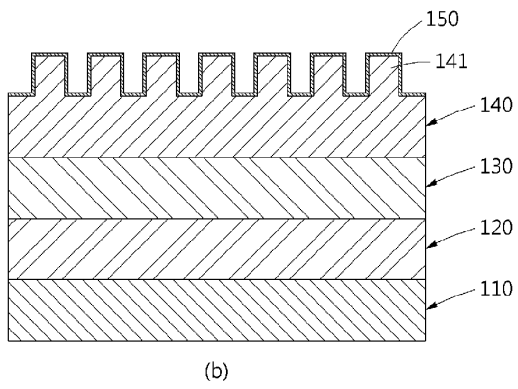
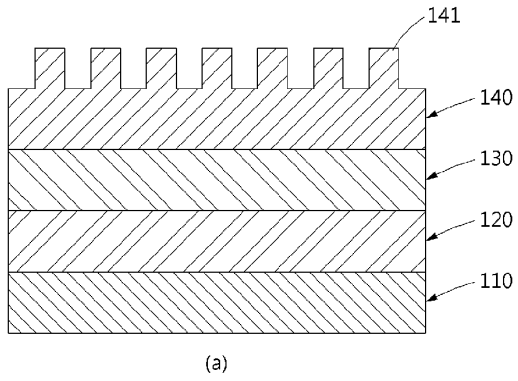
[0080] 도 5 및 도 6을 살펴보면, 수광면에 요철구조를 갖는 소자에서 요철구조의 형태 및 반사방지층의 두께에 따라 상대적 광흡수율의 변화를 확인할 수 있다.

[0081] 이는, 요철구조의 형태에 따라 효과적인 광흡수 경로의 길이를 조절할 수 있고, 흡수된 빛이 외부로 추출되지 않고 수광 소자 내에 트랩(trap) 정도를 요철구조의 형태 및 요철구조 면에 형성된 반사방지층의 두께, 성분 등에 따라 조절할 수 있음을 확인할 수 있다.

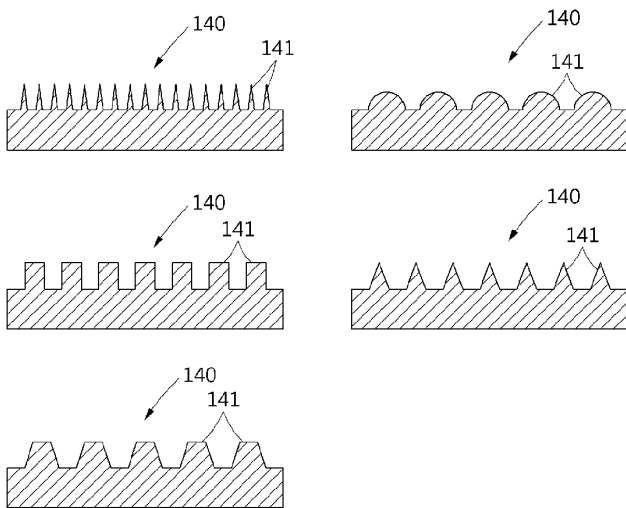
[0082] 본 발명의 바람직한 실시예를 참조하여 설명하지만, 본 발명은 이에 한정되는 것이 아니고, 하기의 특허 청구의 범위, 발명의 상세한 설명 및 첨부된 도면에 기재된 본 발명의 사상 및 영역으로부터 벗어나지 않는 범위 내에서 본 발명을 다양하게 수정 및 변경시킬 수 있다.

도 1

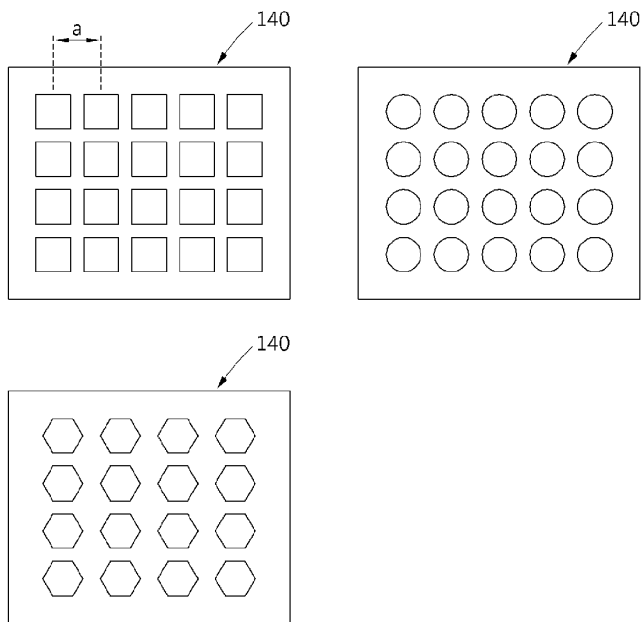
도 2



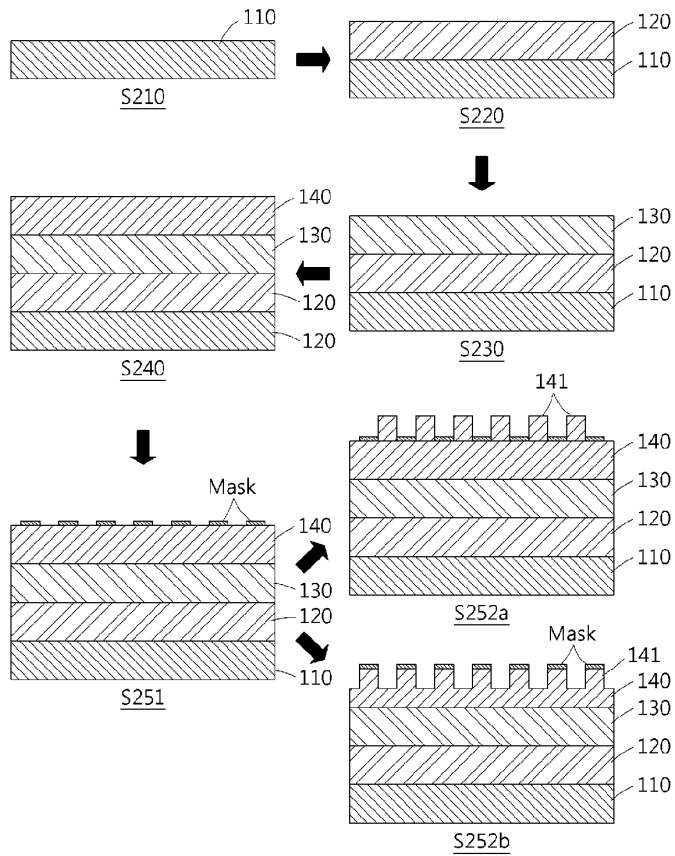
도 3



도 8



도면 4



도면 5

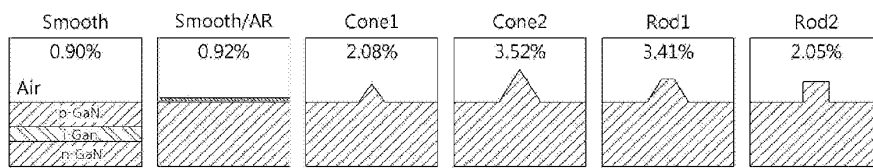
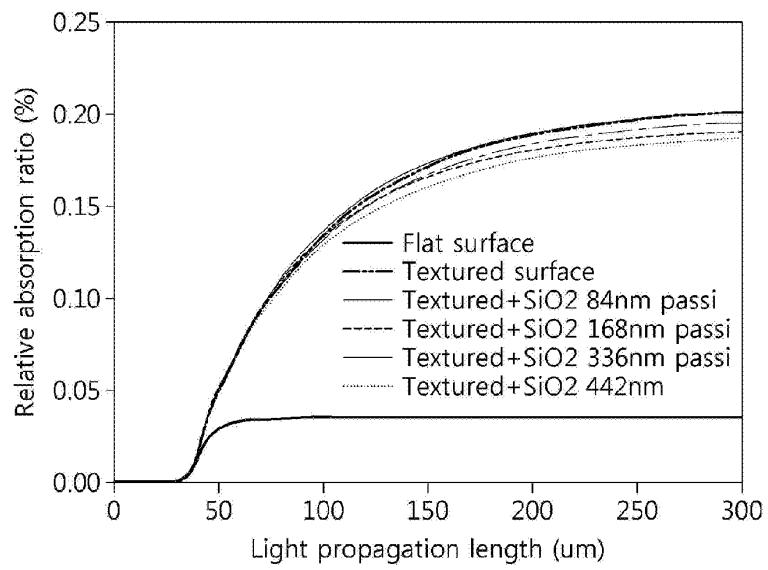


Fig. 6



**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

|                             |   |                        |
|-----------------------------|---|------------------------|
| In re Patent Application    | ) |                        |
| Kun YU et al.               | ) | Art Unit: 1721         |
| Application No.: 17/964,190 | ) | Examiner: Golam Mowla  |
| Filed: October 12, 2022     | ) | Confirmation No.: 7994 |
| For: SOLAR CELL,            | ) |                        |
| MANUFACTURING METHOD        | ) |                        |
| THEREOF, AND                | ) |                        |
| PHOTOVOLTAIC MODULE         | ) |                        |

**INFORMATION DISCLOSURE STATEMENT**

**Mail Stop Amendment – Via EFS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

In accordance with the duty of disclosure as set forth in 37 C.F.R. § 1.56, Applicant hereby submits the following information in conformance with 37 C.F.R. §§ 1.97 and 1.98. In accordance with the policies of the U.S. Patent and Trademark Office, only copies of newly cited foreign patents and non-patent literature are being submitted.

**Foreign Communication – Chinese Office Action**

Applicant notes that the *U.S. and Foreign Patent Documents*: CN-105826405; CN-104350607; CN109545880; CN103325871; KR20190058017; US-2015/0102212; US-2015/0162487; CN-111180538; CN-102683439; listed on the attached Form PTO-1449 were previously cited by CNIPA in a Chinese Office Action mailed **December 5, 2022** (copy and partial English-language translation thereof enclosed) issued in a counterpart Chinese Patent App. No. 202110895225.8.

The undersigned certifies that each item of information contained in this information disclosure statement was first cited in any communication from a foreign patent office in connection with a counterpart foreign application not more than three (3) months prior to the filing of this statement.

It is requested that the accompanying Form PTO-1449 be considered and made of record in the above-identified application and that an Examiner-initialed copy of this form be returned to the undersigned.

The present Information Disclosure Statement is submitted before issuance of an action closing prosecution and is certified under 37 C.F.R. § 1.97(e)(1); therefore, no fee is believed to be necessary at this time.

However, if a fee becomes necessary, the Commissioner is hereby authorized by this paper to charge any additional fees, except the issue fee, during the entire pendency of this application including fees due under 37 C.F.R. §§ 1.16 and 1.17 which may be required, including any required extension of time fees, or credit any overpayment to Deposit Account No. 50-4181.

Respectfully submitted,

/Jeffrey L. Costellia, Reg.#35483/  
Jeffrey L. Costellia  
Registration No. 35,483

**NIXON PEABODY LLP**  
CUSTOMER NO.: 22204  
799 9th Street, N.W., Suite 500  
Washington, DC 20001-4501  
Tel: 202-585-8000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

|                                |   |                        |
|--------------------------------|---|------------------------|
| In re Patent Application       | ) |                        |
| Kun YU et al.                  | ) | Art Unit: 1721         |
| Application No.: 17/964,190    | ) | Examiner: Golam Mowla  |
| Filed: October 12, 2022        | ) | Confirmation No.: 7994 |
| For: SOLAR CELL, MANUFACTURING | ) |                        |
| METHOD THEREOF, AND            | ) |                        |
| PHOTOVOLTAIC MODULE            | ) |                        |

**REQUEST FOR RECONSIDERATION**

**SUBMITTED WITH A TERMINAL DISCLAIMER**

**Mail Stop Amendment - Via EFS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

In response to the **Non-Final Office Action** mailed **December 21, 2022**, please consider Applicant's remarks as follows.

*A Terminal Disclaimer* accompanies this reply.

Any fees required for the Terminal Disclaimer are hereby authorized to be charged to Deposit Account No. 50-4181.

**Remarks begin on page 2** of this paper.

**REMARKS**

The Non-Final Office Action mailed **December 21, 2022** was received and its contents carefully noted. This response is filed within three months of mailing date of the Office Action and therefore is believed to be timely without extension of time. Accordingly, Applicant respectfully submits that this response is being timely filed.

***Status of Claims:***

Claims 1-7, 9, 11-12, 14, 18 and 20-27 were pending in the present application, of which claims 1 and 20 are independent.

By this response, no amendment is made to the claims. Accordingly, claims 1-7, 9, 11-12, 14, 18 and 20-27 remain pending in the present application, of which claims 1 and 20 are independent.

For the reasons set forth in detail below, all claims are believed to be in condition for allowance. Favorable reconsideration is requested.

***Double Patenting***

Claims 1-7, 9, 11-12, 14, 18 and 20-27 stand rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-14 of co-pending U.S. Application No. 17/459,689 (*"the '689 Application"*).

Without conceding in detail the merits of the Examiner's rejections, but to expedite prosecution, Applicant filed a Terminal Disclaimer in compliance with 37 CFR 1.321(c) with respect to *the '689 Application*, which has been approved. Accordingly, Applicant respectfully requests that this double patenting rejection be withdrawn.

***CONCLUSION***

In view of the foregoing, Applicant respectfully requests allowance of the instant application. If a conference would be helpful in expediting prosecution of the instant application, the Examiner is invited to telephone the undersigned to arrange such a conference.

**Except** for issue fees payable under 37 C.F.R. § 1.18, the Commissioner is hereby authorized by this paper to charge any additional fees during the entire pendency of this application including fees due under 37 C.F.R. §§ 1.16 and 1.17 which may be required, including any required extension of time fees, or credit any overpayment to Deposit Account No. 50-4181.

Respectfully submitted,

/Jeffrey L. Costellia, Reg. No. 35,483/  
Jeffrey L. Costellia  
Registration No. 35,483

**NIXON PEABODY LLP**  
CUSTOMER NO.: 22204  
799 9th Street, N.W., Suite 500  
Washington, DC 20001-4501  
Tel: 202-585-8000

|                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                       |                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| <b>Doc Code: DIST.E.FILE</b><br><b>Document Description: Electronic Terminal Disclaimer - Filed</b>                                                                                                                                                                                                                                                     |                                                                                                                       | PTO/SB/25<br>U.S. Patent and Trademark Office<br>Department of Commerce |
| Electronic Petition Request                                                                                                                                                                                                                                                                                                                             | <b>TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION</b> |                                                                         |
| Application Number                                                                                                                                                                                                                                                                                                                                      | 17964190                                                                                                              |                                                                         |
| Filing Date                                                                                                                                                                                                                                                                                                                                             | 12-Oct-2022                                                                                                           |                                                                         |
| First Named Inventor                                                                                                                                                                                                                                                                                                                                    | Kun YU                                                                                                                |                                                                         |
| Attorney Docket Number                                                                                                                                                                                                                                                                                                                                  | 084546-000033USD1                                                                                                     |                                                                         |
| Title of Invention                                                                                                                                                                                                                                                                                                                                      | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE                                                     |                                                                         |
| <input checked="" type="checkbox"/> Filing of terminal disclaimer does not obviate requirement for response under 37 CFR 1.111 to outstanding Office Action<br><br><input checked="" type="checkbox"/> This electronic Terminal Disclaimer is not being used for a Joint Research Agreement.                                                            |                                                                                                                       |                                                                         |
| Owner                                                                                                                                                                                                                                                                                                                                                   | Percent Interest                                                                                                      |                                                                         |
| SHANGHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD.                                                                                                                                                                                                                                                                                             | 100%                                                                                                                  |                                                                         |
| ZHEJIANG JINKO SOLAR CO., LTD.                                                                                                                                                                                                                                                                                                                          | 100%                                                                                                                  |                                                                         |
| The owner(s) of percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending reference Application Number(s) |                                                                                                                       |                                                                         |
| 17459689 filed on 08/27/2021                                                                                                                                                                                                                                                                                                                            |                                                                                                                       |                                                                         |

as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the reference application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said reference application, "as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application," in the event that any such patent granted on the pending reference application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

- ☒ Terminal disclaimer fee under 37 CFR 1.20(d) is included with Electronic Terminal Disclaimer request.
- ☐ I certify, in accordance with 37 CFR 1.4(d)(4), that the terminal disclaimer fee under 37 CFR 1.20(d) required for this terminal disclaimer has already been paid in the above-identified application.

Applicant claims the following fee status:

- ☐ Small Entity
- ☐ Micro Entity
- ☒ Regular Undiscounted

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

- ☒ An attorney or agent registered to practice before the Patent and Trademark Office who is of record in this application
- Registration Number 35483
- ☐ A sole inventor
- ☐ A joint inventor; I certify that I am authorized to sign this submission on behalf of all of the inventors as evidenced by the power of attorney in the application
- ☐ A joint inventor; all of whom are signing this request

|           |                        |
|-----------|------------------------|
| Signature | /Jeffrey L. Costellia/ |
| Name      | Jeffrey L. Costellia   |

\*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).  
Form PTO/SB/96 may be used for making this certification. See MPEP § 324.

| Electronic Patent Application Fee Transmittal      |                 |                                                                   |               |                             |
|----------------------------------------------------|-----------------|-------------------------------------------------------------------|---------------|-----------------------------|
| <b>Application Number:</b>                         |                 | 17964190                                                          |               |                             |
| <b>Filing Date:</b>                                |                 | 12-Oct-2022                                                       |               |                             |
| <b>Title of Invention:</b>                         |                 | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |               |                             |
| <b>First Named Inventor/Applicant Name:</b>        |                 | Kun YU                                                            |               |                             |
| <b>Filer:</b>                                      |                 | Jeffrey Costellia/Donald Sias                                     |               |                             |
| <b>Attorney Docket Number:</b>                     |                 | 084546-000033USD1                                                 |               |                             |
| Filed as Large Entity                              |                 |                                                                   |               |                             |
| <b>Filing Fees for Utility under 35 USC 111(a)</b> |                 |                                                                   |               |                             |
| <b>Description</b>                                 | <b>Fee Code</b> | <b>Quantity</b>                                                   | <b>Amount</b> | <b>Sub-Total in USD(\$)</b> |
| <b>Basic Filing:</b>                               |                 |                                                                   |               |                             |
| STATUTORY OR TERMINAL DISCLAIMER                   | 1814            | 1                                                                 | 170           | 170                         |
| <b>Pages:</b>                                      |                 |                                                                   |               |                             |
| <b>Claims:</b>                                     |                 |                                                                   |               |                             |
| <b>Miscellaneous-Filing:</b>                       |                 |                                                                   |               |                             |
| <b>Petition:</b>                                   |                 |                                                                   |               |                             |
| <b>Patent-Appeals-and-Interference:</b>            |                 |                                                                   |               |                             |
| <b>Post-Allowance-and-Post-Issuance:</b>           |                 |                                                                   |               |                             |

| Description        | Fee Code | Quantity | Amount | Sub-Total in USD(\$) |
|--------------------|----------|----------|--------|----------------------|
| Extension-of-Time: |          |          |        |                      |
| Miscellaneous:     |          |          |        |                      |
| Total in USD (\$)  |          |          |        | 170                  |

Doc Code: DISQ.E.FILE

Document Description: Electronic Terminal Disclaimer – Approved

Application No.: 17964190

Filing Date: 12-Oct-2022

Applicant/Patent under Reexamination: YU et al.

Electronic Terminal Disclaimer filed on March 3, 2023

☒ APPROVED

**This patent is subject to a terminal disclaimer**

☐ DISAPPROVED

Approved/Disapproved by: Electronic Terminal Disclaimer automatically approved by EFS-Web

U.S. Patent and Trademark Office

| Electronic Acknowledgement Receipt          |                                                                   |
|---------------------------------------------|-------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 47620839                                                          |
| <b>Application Number:</b>                  | 17964190                                                          |
| <b>International Application Number:</b>    |                                                                   |
| <b>Confirmation Number:</b>                 | 7994                                                              |
| <b>Title of Invention:</b>                  | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |
| <b>First Named Inventor/Applicant Name:</b> | Kun YU                                                            |
| <b>Customer Number:</b>                     | 22204                                                             |
| <b>Filer:</b>                               | Jeffrey Costellia/Donald Sias                                     |
| <b>Filer Authorized By:</b>                 | Jeffrey Costellia                                                 |
| <b>Attorney Docket Number:</b>              | 084546-000033USD1                                                 |
| <b>Receipt Date:</b>                        | 03-MAR-2023                                                       |
| <b>Filing Date:</b>                         | 12-OCT-2022                                                       |
| <b>Time Stamp:</b>                          | 06:53:42                                                          |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)                                       |

### Payment information:

|                                                                                                                |                  |
|----------------------------------------------------------------------------------------------------------------|------------------|
| Submitted with Payment                                                                                         | yes              |
| Payment Type                                                                                                   | DA               |
| Payment was successfully received in RAM                                                                       | \$170            |
| RAM confirmation Number                                                                                        | E202333753369900 |
| Deposit Account                                                                                                |                  |
| Authorized User                                                                                                |                  |
| The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: |                  |

| <b>File Listing:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                        |                          |                                          |                  |                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|--------------------------|------------------------------------------|------------------|------------------|
| Document Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Document Description                   | File Name                | File Size(Bytes)/<br>Message Digest      | Multi Part /.zip | Pages (if appl.) |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Terminal Disclaimer-Filed (Electronic) | eTerminal-Disclaimer.pdf | 43011                                    | no               | 2                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                        |                          | fc6d9d6ba533402a789aac0676e0f61321b6d18d |                  |                  |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                        |                          |                                          |                  |                  |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                        |                          |                                          |                  |                  |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Fee Worksheet (SB06)                   | fee-info.pdf             | 37940                                    | no               | 2                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                        |                          | ead73eee512c081c56375a95b9473844264bab07 |                  |                  |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                        |                          |                                          |                  |                  |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                        |                          |                                          |                  |                  |
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| <p><b>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</b></p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p> |                                        |                          |                                          |                  |                  |



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| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 17/964,190         | 10/12/2022            | Kun YU                | 084546-000033USD1      |

**CONFIRMATION NO. 7994**

22204  
NIXON PEABODY, LLP  
799 Ninth Street, NW  
SUITE 500  
WASHINGTON, DC 20001

## PUBLICATION NOTICE



OC000000137416692

**Title:**SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE

**Publication No.**US-2023-0050761-A1

**Publication Date:**02/16/2023

## NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at [www.uspto.gov](http://www.uspto.gov). The direct link to access the publication is currently <http://www.uspto.gov/patft/>.

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|----------------------|-------------|----------------------|---------------------|------------------|
| APPLICATION NO.      | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
| 17/964,190           | 10/12/2022  | Kun YU               | 084546-000033USD1   | 7994             |
| 22204                | 7590        | 12/21/2022           | EXAMINER            |                  |
| NIXON PEABODY, LLP   |             |                      | MOWLA, GOLAM        |                  |
| 799 Ninth Street, NW |             |                      |                     |                  |
| SUITE 500            |             |                      |                     |                  |
| WASHINGTON, DC 20001 |             |                      |                     |                  |
|                      |             | ART UNIT             | PAPER NUMBER        |                  |
|                      |             | 1721                 |                     |                  |
|                      |             | NOTIFICATION DATE    | DELIVERY MODE       |                  |
|                      |             | 12/21/2022           | ELECTRONIC          |                  |

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipairlink@nixonpeabody.com  
nppatent@nixonpeabody.com



## DETAILED ACTION

### *Notice of Pre-AIA or AIA Status*

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

### *Double Patenting*

2. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the “right to exclude” granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on nonstatutory double patenting provided the reference application or patent either is shown to be commonly owned with the examined application, or claims an invention made as a result of activities undertaken within the

scope of a joint research agreement. See MPEP § 717.02 for applications subject to examination under the first inventor to file provisions of the AIA as explained in MPEP § 2159. See MPEP § 2146 *et seq.* for applications not subject to examination under the first inventor to file provisions of the AIA. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The USPTO Internet website contains terminal disclaimer forms which may be used. Please visit [www.uspto.gov/patent/patents-forms](http://www.uspto.gov/patent/patents-forms). The filing date of the application in which the form is filed determines what form (e.g., PTO/SB/25, PTO/SB/26, PTO/AIA/25, or PTO/AIA/26) should be used. A web-based eTerminal Disclaimer may be filled out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to [www.uspto.gov/patents/process/file/efs/guidance/eTD-info-1.jsp](http://www.uspto.gov/patents/process/file/efs/guidance/eTD-info-1.jsp).

3. Claims 1-7, 9, 11-12, 14, 18 and 20-27 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-14 of copending Application No. 17/459,689. The claims of copending application encompass all the limitations of pending claims.

This is a provisional nonstatutory double patenting rejection.

### ***Conclusion***

4. The search did not reveal any pertinent art that discloses a solar cell as required by the instant claims. WO 2016/129481 A1 to Sakai et al. is the closest prior art.

WO 2016/129481 A1 to Sakai et al. discloses an optoelectric transducer 10 which functions as a solar cell (refer to paragraph [0025]-[0112], [0224], and Fig.1 A-5), consist of a n

type single crystal silicon substrate, and (refer to paragraph [0028]) with the semiconductor substrate 1 which has texture structure on a rear face, consist of silicon nitride and (refer to paragraph [0029] and [0039]) with the antireflection layer 2 of the aforementioned semiconductor substrate 1 which is placed in front, and placed between the aforementioned antireflection layer 2 and a light receiving surface, and (refer to paragraph [0039]) with the amorphous semiconductor layer which improves the passivation nature of a light receiving surface, it consists of an oxide of silicon and is placed on the aforementioned texture structure in the rear face of the aforementioned semiconductor substrate 1, (Refer to paragraph [0030] and [0041]-[0042]) with the passivation film 3 which has the film thickness which can tunnel a carrier, (Refer to paragraph [0031] and [0043]) with the n type amorphous semiconductor layer 4 which is placed at the surface of the aforementioned passivation film 3, it is placed at the surface of the aforementioned n type amorphous semiconductor layer 4, and the protective film 8 which has the passivation nature to the aforementioned n type amorphous semiconductor layer 4, and the aforementioned optoelectric transducer 10 including (paragraph [0038] and refer to [0078]) are described. The textured structure is pyramid form and truncated four-sided pyramidal rugged structure and an actual texture is shown in Fig. 2 about the aforementioned texture structure at paragraph [0045]-[0047] of Sakai, which shows multiple unevenness with sizes or various form is formed. Sakai further discloses that in paragraph [0028] that the size of a texture is less than 15 micrometers.

However, Sakai does not clearly show among the overlapping unevenness about the distance of the top face of an outermost protruding part, and the top face of the protruding part which adjoins it.

***Correspondence/Contact Information***

Any inquiry concerning this communication or earlier communications from the examiner should be directed to GOLAM MOWLA whose telephone number is (571)270-5268. The examiner can normally be reached on M-Th, 7am - 4pm.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Allison Bourke can be reached on 303-297-4684. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <https://ppair-my.uspto.gov/pair/PrivatePair>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/GOLAM MOWLA/  
Primary Examiner, Art Unit 1721

|                                          |                                       |  |                                                         |             |
|------------------------------------------|---------------------------------------|--|---------------------------------------------------------|-------------|
| <b><i>Notice of References Cited</i></b> | Application/Control No.<br>17/964,190 |  | Applicant(s)/Patent Under<br>Reexamination<br>YU et al. |             |
|                                          | Examiner<br>GOLAM MOWLA               |  | Art Unit<br>1721                                        | Page 1 of 1 |

**U.S. PATENT DOCUMENTS**

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Name        | CPC Classification | US Classification |
|---|---|--------------------------------------------------|-----------------|-------------|--------------------|-------------------|
| * | A | US-20170179325-A1                                | 06-2017         | CHUNG; Indo | H01L31/0682        | 1/1               |
|   | B |                                                  |                 |             |                    |                   |
|   | C |                                                  |                 |             |                    |                   |
|   | D |                                                  |                 |             |                    |                   |
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|   | M |                                                  |                 |             |                    |                   |

**FOREIGN PATENT DOCUMENTS**

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Country | Name        | CPC Classification |
|---|---|--------------------------------------------------|-----------------|---------|-------------|--------------------|
|   | N | KR-20180058099-A                                 | 05-2018         | KR      | HA JUNG MIN | H01L31/02366       |
|   | O | JP-6746854-B2                                    | 08-2020         | JP      | BUENA M M   | H01L31/02167       |
|   | P | JP-2004273829-A                                  | 09-2004         | JP      | NUNOI T     | H01L31/03529       |
|   | Q | CN-108963013-A                                   | 12-2018         | CN      | HUANG S     | H01L31/02167       |
|   | R |                                                  |                 |         |             |                    |
|   | S |                                                  |                 |         |             |                    |
|   | T |                                                  |                 |         |             |                    |

**NON-PATENT DOCUMENTS**

| * |   | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
|---|---|-------------------------------------------------------------------------------------------|
|   | U |                                                                                           |
|   | V |                                                                                           |
|   | W |                                                                                           |
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**Notice of References Cited**

Part of Paper No. 20221215

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|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------------------------------------------------|
| <b><i>Search Notes</i></b><br> | <b>Application/Control No.</b><br>17/964,190 | <b>Applicant(s)/Patent Under Reexamination</b><br>YU et al. |
|                                                                                                                 | <b>Examiner</b><br>GOLAM MOWLA               | <b>Art Unit</b><br>1721                                     |

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|---------------------------------------|-------------|-----------------|
| <b>CPC - Searched*</b>                |             |                 |
| <b>Symbol</b>                         | <b>Date</b> | <b>Examiner</b> |
| H01L31/02366,03685,068,1824,1868.cpc. | 12/15/2022  | gm              |

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| <b>CPC Combination Sets - Searched*</b> |             |                 |
| <b>Symbol</b>                           | <b>Date</b> | <b>Examiner</b> |
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| <b>US Classification - Searched*</b> |                 |             |                 |
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| <b>Search Notes</b>                          |             |                 |
| <b>Search Notes</b>                          | <b>Date</b> | <b>Examiner</b> |
| PE2E Search - CPC with keywords              | 12/15/2022  | gm              |
| Inventor and Assignee Search - PALM and PE2E | 12/15/2022  | gm              |

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| /GOLAM MOWLA/<br>Primary Examiner, Art Unit 1721 |  |
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|                                                                                                                                       |   |    |   | Application Number       | Not Yet Assigned  |
|                                                                                                                                       |   |    |   | Filing Date              | October 12, 2022  |
|                                                                                                                                       |   |    |   | First Named Inventor     | Kun YU et al.     |
|                                                                                                                                       |   |    |   | Art Unit                 | Not Yet Assigned  |
|                                                                                                                                       |   |    |   | Examiner Name            | Not Yet Assigned  |
| Sheet                                                                                                                                 | 1 | of | 2 | Attorney Docket Number   | 084546-000044USD1 |

| U.S. PATENT DOCUMENTS |                       |                                            |                                |                                                    |                                                                                 |
|-----------------------|-----------------------|--------------------------------------------|--------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------|
| Examiner Initials*    | Cite No. <sup>1</sup> | U.S. Patent Document                       | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines, Where<br>Relevant Passages or Relevant<br>Figures Appear |
|                       |                       | Number - Kind Code <sup>2</sup> (if known) |                                |                                                    |                                                                                 |
|                       |                       | US-2018/0182905 A1                         | 06-28-2018                     | NAM et al.                                         |                                                                                 |
|                       |                       | US-2018/0315866 A1                         | 11-01-2018                     | CHEONG et al.                                      |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
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| FOREIGN PATENT DOCUMENTS       |                       |                           |                                                             |                                |                                                      |                                                                                    |                |
|--------------------------------|-----------------------|---------------------------|-------------------------------------------------------------|--------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------|----------------|
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|                                |                       | Country Code <sup>3</sup> | Number <sup>4</sup><br>Kind Code <sup>5</sup><br>(if known) |                                |                                                      |                                                                                    |                |
|                                |                       | CN-                       | 111628049                                                   | 09-04-2020                     |                                                      |                                                                                    | Abstract       |
|                                |                       | CN-                       | 212750903                                                   | 03-19-2021                     |                                                      |                                                                                    | Abstract       |
|                                |                       | EP-                       | 2149915                                                     | 02-03-2010                     |                                                      |                                                                                    | Eng.           |
|                                |                       | EP-                       | 2645421                                                     | 10-02-2013                     |                                                      |                                                                                    | Eng.           |
|                                |                       | WO-                       | 2015/122257                                                 | 08-20-2015                     |                                                      |                                                                                    | Abstract       |
|                                |                       | CN-                       | 112599615                                                   | 04-02-2021                     |                                                      |                                                                                    | Abstract       |
|                                |                       | JP-                       | 2012-216788                                                 | 11-08-2012                     |                                                      |                                                                                    | Abstract       |
|                                |                       | WO-                       | 2016/129481                                                 | 08-18-2016                     |                                                      |                                                                                    | Abstract       |
|                                |                       |                           |                                                             |                                |                                                      |                                                                                    |                |
|                                |                       |                           |                                                             |                                |                                                      |                                                                                    |                |

| OTHER PRIOR ART - NON PATENT LITERATURE DOCUMENTS |                       |                                                                                                                                                                                                                                                                 |                |
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| Examiner Initials*                                | Cite No. <sup>1</sup> | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published. | T <sup>2</sup> |
|                                                   |                       | Extended European Search Report for EP App. No. 21194044.0, mailed Dec 2, 2021, 7 pages.                                                                                                                                                                        | Eng.           |
|                                                   |                       | Japan Office Action (Application No. 2021-137285) mailed January 11, 2022 (17 pages).                                                                                                                                                                           | Eng.           |
|                                                   |                       |                                                                                                                                                                                                                                                                 |                |

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|--------------------|---------------|-----------------|------------|
| Examiner Signature | /GOLAM MOWLA/ | Date Considered | 12/15/2022 |
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<sup>1</sup> Applicant's unique citation designation number (optional). <sup>2</sup> See Kinds Codes of USPTO Patent Documents at [www.uspto.gov](http://www.uspto.gov) or MPEP 901.04. <sup>3</sup> Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). <sup>4</sup> For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. <sup>5</sup> Kind of document by the

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|                                                                                                                                           |   |    |   | Application Number       | Not Yet Assigned  |
|                                                                                                                                           |   |    |   | Filing Date              | October 12, 2022  |
|                                                                                                                                           |   |    |   | First Named Inventor     | Kun YU et al.     |
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|                                                                                                                                           |   |    |   | Examiner Name            | Not Yet Assigned  |
| Sheet                                                                                                                                     | 2 | of | 2 | Attorney Docket Number   | 084546-000044USD1 |

| U.S. PATENT DOCUMENTS |                          |                                            |                                |                                                    |                                                                                 |
|-----------------------|--------------------------|--------------------------------------------|--------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------|
| Examiner<br>Initials* | Cite<br>No. <sup>1</sup> | U.S. Patent Document                       | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines, Where<br>Relevant Passages or Relevant<br>Figures Appear |
|                       |                          | Number - Kind Code <sup>2</sup> (if known) |                                |                                                    |                                                                                 |
|                       |                          | US-2018/0018295                            | 01-18-2018                     | Chen et al.                                        |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
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|                       |                          | US-                                        |                                |                                                    |                                                                                 |

| FOREIGN PATENT DOCUMENTS |                          |                                                                                    |                                |                                                    |                                                                                    |                |
|--------------------------|--------------------------|------------------------------------------------------------------------------------|--------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------|----------------|
| Examiner<br>Initials*    | Cite<br>No. <sup>1</sup> | Foreign Patent Document                                                            | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines,<br>Where Relevant Passages<br>or Relevant Figures<br>Appear | T <sup>6</sup> |
|                          |                          | Country Code <sup>3</sup> Number <sup>4</sup><br>Kind Code <sup>5</sup> (if known) |                                |                                                    |                                                                                    |                |
|                          |                          | CN-110931596                                                                       | 03-27-2020                     |                                                    |                                                                                    | Abstract       |
|                          |                          | JP-6-61515                                                                         | 03-04-1994                     |                                                    |                                                                                    | Abstract       |
|                          |                          |                                                                                    |                                |                                                    |                                                                                    |                |
|                          |                          |                                                                                    |                                |                                                    |                                                                                    |                |

| OTHER PRIOR ART - NON PATENT LITERATURE DOCUMENTS |                          |                                                                                                                                                                                                                                                                 |                |
|---------------------------------------------------|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Examiner<br>Initials*                             | Cite<br>No. <sup>1</sup> | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published. | T <sup>2</sup> |
|                                                   |                          | Notification of Reasons for Refusal for Japanese App. No. 2022-084397, mailed August 2, 2022 (4 pages).                                                                                                                                                         | Machine Trans. |
|                                                   |                          | Australian Notice of Acceptance for Application No. 2021225144, mailed June 10, 2022 (6 pages).                                                                                                                                                                 | Eng.           |
|                                                   |                          |                                                                                                                                                                                                                                                                 |                |

|                       |  |                    |  |
|-----------------------|--|--------------------|--|
| Examiner<br>Signature |  | Date<br>Considered |  |
|-----------------------|--|--------------------|--|

\*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

<sup>1</sup> Applicant's unique citation designation number (optional). <sup>2</sup> See Kinds Codes of USPTO Patent Documents at [www.uspto.gov](http://www.uspto.gov) or MPEP 901.04. <sup>3</sup> Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). <sup>4</sup> For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. <sup>5</sup> Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. <sup>6</sup> Applicant is to place a check mark here if English language Translation is attached.

<sup>1</sup> Applicant's unique citation designation number (optional). <sup>2</sup> Applicant is to place a check mark here if English language Translation is attached.

# PE2E SEARCH - Search History (Prior Art)

| Ref # | Hits  | Search Query                                                                                                                                                                                                                   | DBs                                                                                                                                                                                                                                                                                                                  | Default Operator | Plurals | British Equivalents | Time Stamp          |
|-------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------|---------------------|---------------------|
| L1    | 16    | ((("SHANGHAI") near3 ("JINKO") near3 ("GREEN") near3 ("ENERGY") near3 ("ENTERPRISE") near3 ("MANAGEMENT") near3 ("CO") near3 ("LTD")) OR ((("ZHEJIANG") near3 ("JINKO") near3 ("SOLAR") near3 ("CO") near3 ("LTD")))).AS,AANM. | (USPAT)                                                                                                                                                                                                                                                                                                              | OR               | ON      | ON                  | 2022/10/22 12:08 PM |
| L2    | 922   | ((("YU") near3 ("Kun")) OR ((("LIU") near3 ("Changming")) OR ((("ZHANG") near3 ("Xinyu")))).INV.                                                                                                                               | (US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT)                                                                                                                                                                                                                                                                          | OR               | ON      | ON                  | 2022/10/22 12:09 PM |
| L3    | 3299  | ((("SHANGHAI") near3 ("JINKO") near3 ("GREEN") near3 ("ENERGY") near3 ("ENTERPRISE") near3 ("MANAGEMENT") near3 ("CO") near3 ("LTD")) OR ((("ZHEJIANG") near3 ("JINKO") near3 ("SOLAR") near3 ("CO") near3 ("LTD")))).AS,AANM. | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB) | OR               | ON      | ON                  | 2022/10/22 12:11 PM |
| L4    | 38497 | ((("YU") near3 ("Kun")) OR ((("LIU") near3 ("Changming")) OR ((("ZHANG") near3 ("Xinyu")))).INV.                                                                                                                               | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB) | OR               | ON      | ON                  | 2022/10/22 12:11 PM |
| L5    | 36708 | H01L31/02366,03685,068,1824,1868.cpc.                                                                                                                                                                                          | (US-PGPUB; USPAT; USOCR; FIT (AP, AT,                                                                                                                                                                                                                                                                                | OR               | ON      | ON                  | 2022/10/22 12:12 PM |

|     |     |                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |    |    |    |                     |
|-----|-----|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|---------------------|
| L6  | 241 | (L3 L4 ) AND L5                                       | AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)<br>(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB) | OR | ON | ON | 2022/10/22 12:12 PM |
| L7  | 8   | ("20180182905" "20180315866" "20180018295").pn.       | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)                                                                                                                                                                                                                                                                                   | OR | ON | ON | 2022/10/22 12:16 PM |
| L8  | 3   | ("20180182905" "20180315866" "20180018295").pn.       | (US-PGPUB)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | OR | ON | ON | 2022/10/22 12:16 PM |
| L9  | 2   | ("2018/0315866").urpn. AND (PGPB   USPT   USOC).dbnm. | (US-PGPUB; USPAT; USOCR)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | OR | ON | ON | 2022/10/22 12:16 PM |
| L10 | 0   | ("2018/0182905").urpn. AND (PGPB   USPT   USOC).dbnm. | (US-PGPUB; USPAT; USOCR)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | OR | ON | ON | 2022/10/22 12:16 PM |
| L11 | 1   | ("2018/0018295").urpn.                                | (US-PGPUB; USPAT;                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | OR | ON | ON | 2022/10/22          |

|     |        |                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                |    |    |    |                                 |
|-----|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|---------------------------------|
| L12 | 283181 | AND (PGPB   USPT   USOC).dbnm.<br>(semi\$1conduct\$4 Si silicon) near2 (support substrate structure layer film) WITH (textur\$4 uneven\$4 convex\$4 concav\$4 irregularit\$4 corrugat\$4 roughness curvature)                                                  | USOCR)<br>(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB) | OR | ON | ON | 12:16 PM<br>2022/10/22 02:11 PM |
| L13 | 7737   | H01L31/02366,03685,068,1824,1868.cpc. AND L12                                                                                                                                                                                                                  | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)           | OR | ON | ON | 2022/10/22 02:11 PM             |
| L14 | 4      | H01L31/02366,03685,068,1824,1868.cpc. AND (semi\$1conduct\$4 Si silicon) near2 (support substrate structure layer film) WITH (textur\$4 uneven\$4 convex\$4 concav\$4 irregularit\$4 corrugat\$4 roughness curvature) WITH (non\$1pyramid\$4 "not pyramid\$4") | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)           | OR | ON | ON | 2022/10/22 02:12 PM             |
| L15 | 308    | H01L31/02366,03685,068,1824,1868.cpc. AND (semi\$1conduct\$4 Si silicon) near2 (support substrate structure layer film) WITH (textur\$4 uneven\$4 convex\$4                                                                                                    | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS,                                                                                                                                                                              | OR | ON | ON | 2022/10/22 02:14 PM             |

|     |      |                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                   |    |    |    |                        |
|-----|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|------------------------|
| L16 | 0    | concav\$4 irregularit\$4<br>corrugat\$4 roughness<br>curvature) WITH<br>(poly\$1gonal<br>trapezoid\$4 square)                                                                                                                                                       | IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB)                                                                                                                                                                        | OR | ON | ON | 2022/10/22<br>02:14 PM |
| L17 | 150  | L15 AND<br>(non\$1pyramid\$4 "not<br>pyramid\$4")                                                                                                                                                                                                                   | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/10/22<br>02:14 PM |
| L18 | 4826 | L15 NOT pyramid\$4                                                                                                                                                                                                                                                  | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/10/22<br>02:15 PM |
|     |      | H01L31/02366,03685,0<br>68,1824,1868.cpc. AND<br>(semi\$1conduct\$4 Si<br>silicon) near2 (support<br>substrate structure layer<br>film) WITH (textur\$4<br>uneven\$4 convex\$4<br>concav\$4 irregularit\$4<br>corrugat\$4 roughness<br>curvature) NOT<br>pyramid\$6 | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/10/22<br>02:15 PM |

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                   |    |    |    |                        |
|-----|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|------------------------|
| L19 | 8  | L17 AND (structure<br>micro\$1structure<br>nano\$1structure) WITH<br>overlap\$4                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/10/22<br>02:23 PM |
| L20 | 42 | (Artificial Intelligence)<br>More like doc:<br>CN-115020503-A<br>Text:<br>(AU-2021225144-B1<br>OR AU-2022206802-A1<br>OR JP-7082235-B1 OR<br>CN-113540269-B OR<br>CN-114649427-A OR<br>CN-113421949-B OR<br>CN-113421949-A OR<br>CN-113540269-A OR<br>JP-7152580-B1 OR US-<br>20220123164-A1 OR<br>CN-111933752-A OR<br>CN-113299771-A OR<br>US-20180315866-A1<br>OR WO-2022069068-<br>A1 OR US-<br>20200350445-A1 OR<br>JP-WO2019163786-A1<br>OR JP-6058212-B2 OR<br>JP-WO2019163784-A1<br>OR WO-2020218000-<br>A1 OR JP-<br>WO2020218000-<br>A1).did. | (US-PGPUB; USPAT;<br>USOCR; FIT (AU, AP,<br>AT, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, OA, RU, SU, WO,<br>MC, MD, MY, NL, NO,<br>NZ, PH, PL, PT, RO,<br>RS, SE, SG, SI, SK,<br>TH, TN, TR, TW, UA,<br>VN); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/10/22<br>02:26 PM |
| L21 | 38 | (Artificial Intelligence)<br>More like doc:<br>JP-7082235-B1<br>Text:<br>(AU-2021225144-B1<br>OR AU-2022206802-A1<br>OR CN-115020503-A<br>OR CN-113540269-B<br>OR CN-114649427-A<br>OR CN-113540269-A<br>OR JP-7152580-B1 OR<br>US-20220123164-A1<br>OR CN-112635591-A<br>OR KR-101673565-B1                                                                                                                                                                                                                                                            | (US-PGPUB; USPAT;<br>USOCR; FIT (AU, AP,<br>AT, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, OA, RU, SU, WO,<br>MC, MD, MY, NL, NO,<br>NZ, PH, PL, PT, RO,<br>RS, SE, SG, SI, SK,<br>TH, TN, TR, TW, UA,<br>VN); FPRS; EPO;                              | OR | ON | ON | 2022/10/22<br>02:26 PM |

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|-----|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|------------------------|
| L22 | 44 | <p>OR CN-113345970-A<br/>OR KR-20120080583-A<br/>OR JP-<br/>WO2019163786-A1 OR<br/>CN-111524982-A OR<br/>JP-WO2019163784-A1<br/>OR US-20180315866-<br/>A1 OR JP-<br/>WO2019138613-A1 OR<br/>US-20200350445-A1<br/>OR KR-20180119969-A<br/>OR WO-2020218000-<br/>A1).did.</p> <p>(Artificial Intelligence)<br/>More like doc:<br/>CN-114649427-A</p> <p>Text:<br/>(CN-113540269-B OR<br/>CN-113540269-A OR<br/>CN-115020503-A OR<br/>AU-2022206802-A1 OR<br/>AU-2021225144-B1 OR<br/>JP-7152580-B1 OR<br/>CN-113421949-B OR<br/>CN-113421949-A OR<br/>CN-114597285-A OR<br/>EP-3806165-A1 OR<br/>CN-114038921-A OR<br/>JP-2018107468-A OR<br/>JP-6598091-B2 OR<br/>CN-114038928-A OR<br/>CN-114512555-A OR<br/>AU-2010296714-A1 OR<br/>EP-2479804-A1 OR<br/>WO-2021128831-A1<br/>OR CN-114613881-A<br/>OR EP-2479804-<br/>B1).did.</p> | <p>JPO; DERWENT;<br/>IBM_TDB)</p> <p>(US-PGPUB; USPAT;<br/>USOCR; FIT (AU, AP,<br/>AT, BE, BG, BR, BY,<br/>CA, CH, CN, CS, CU,<br/>CZ, DD, DE, DK, EA,<br/>EE, EP, ES, FI, FR, GB,<br/>HR, HU, ID, IE, IL, IS,<br/>IT, JP, KR, LT, LU, LV,<br/>MA, OA, RU, SU, WO,<br/>MC, MD, MY, NL, NO,<br/>NZ, PH, PL, PT, RO,<br/>RS, SE, SG, SI, SK,<br/>TH, TN, TR, TW, UA,<br/>VN); FPRS; EPO;<br/>JPO; DERWENT;<br/>IBM_TDB)</p> | OR | ON | ON | 2022/10/22<br>02:27 PM |
| L23 | 41 | <p>(Artificial Intelligence)<br/>More like doc:<br/>CN-113540269-B</p> <p>Text:<br/>(CN-113540269-A OR<br/>CN-114649427-A OR<br/>CN-115020503-A OR<br/>AU-2022206802-A1 OR<br/>JP-7152580-B1 OR AU-<br/>2021225144-B1 OR<br/>CN-113421949-A OR<br/>CN-113421949-B OR<br/>CN-114551606-A OR<br/>CN-113964212-B OR<br/>JP-2018107468-A OR<br/>JP-6598091-B2 OR EP-<br/>4002495-A2 OR US-<br/>20220262967-A1 OR<br/>WO-2014064929-A1</p>                                                                                                                                                                                                                                                                                                                                                                                                 | <p>(US-PGPUB; USPAT;<br/>USOCR; FIT (AU, AP,<br/>AT, BE, BG, BR, BY,<br/>CA, CH, CN, CS, CU,<br/>CZ, DD, DE, DK, EA,<br/>EE, EP, ES, FI, FR, GB,<br/>HR, HU, ID, IE, IL, IS,<br/>IT, JP, KR, LT, LU, LV,<br/>MA, OA, RU, SU, WO,<br/>MC, MD, MY, NL, NO,<br/>NZ, PH, PL, PT, RO,<br/>RS, SE, SG, SI, SK,<br/>TH, TN, TR, TW, UA,<br/>VN); FPRS; EPO;<br/>JPO; DERWENT;<br/>IBM_TDB)</p>                                   | OR | ON | ON | 2022/10/22<br>02:27 PM |

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|-----|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|------------------------|
| L24 | 109 | OR JP-<br>WO2014064929-A1 OR<br>JP-6308438-B2 OR AU-<br>2010296714-A1 OR<br>KR-102257485-B1 OR<br>WO-2021128831-<br>A1).did.<br><br>L20 L21 L22 L23                                                                                                                                                                                                                                   | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/10/22<br>02:27 PM |
| L25 | 0   | L24 AND (structure<br>micro\$1structure<br>nano\$1structure) WITH<br>overlap\$4                                                                                                                                                                                                                                                                                                       | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/10/22<br>02:28 PM |
| L26 | 44  | (Artificial Intelligence)<br>Similar to:<br>Unpublished Application<br>#<br>Text:<br>(US-20220302334-A1<br>OR KR-20170074172-A<br>OR KR-20180058099-A<br>OR CN-108110072-B<br>OR KR-20190077099-A<br>OR JP-2017539093-A<br>OR EP-3373339-B1 OR<br>US-20100224229-A1<br>OR EP-3373339-A1 OR<br>JP-2017005253-A OR<br>KR-20170097662-A OR<br>JP-2017525126-A OR<br>JP-6411407-B2 OR KR- | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO))                                         | OR | ON | ON | 2022/10/22<br>02:35 PM |

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                    |    |    |    |                     |
|-----|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|---------------------|
| L27 | 42 | <p>20180081268-A OR US-9577126-B2 OR JP-6453297-B2 OR US-10763381-B2 OR JP-6746854-B2 OR JP-2017118112-A OR US-20190131477-A1 OR CN-108963013-B OR TW-201618316-A OR KR-20160145484-A OR KR-101751727-B1 OR KR-20200039839-A OR US-20190019904-A1 OR WO-2013161023-A1 OR US-10957809-B2 OR KR-102100909-B1 OR KR-101995833-B1 OR CN-106898658-A OR KR-20180064194-A OR US-20150380599-A1 OR CN-114127961-A OR EP-3161879-A1 OR KR-101466530-B1 OR US-20150083183-A1 OR CN-107258020-A OR EP-3038164-A1 OR CN-108963013-A OR CN-104254922-A OR EP-3238271-A1 OR WO-2016102471-A1 OR EP-2828897-B1 OR EP-3038164-B1 OR US-20170179325-A1 OR JP-6552011-B2 OR US-20200091366-A1 OR US-20180006164-A1 OR US-20210249551-A1).did.</p> <p>(Artificial Intelligence) Similar to: Unpublished Application #</p> <p>Text:<br/>(CN-108110072-B OR KR-20180058099-A OR JP-2017525126-A OR TW-201618316-A OR US-10763381-B2 OR KR-20170097662-A OR JP-2017539093-A OR US-20150380599-A1 OR US-9577126-B2 OR EP-3161879-A1 OR EP-3238271-A1 OR WO-2016102471-A1 OR US-20180006164-</p> | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO)) | OR | ON | ON | 2022/10/22 02:36 PM |
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|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                    |    |    |    |                     |
|-----|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|---------------------|
| L28 | 44 | <p>A1 OR JP-6552011-B2 OR EP-3038164-A1 OR EP-3038164-B1 OR CN-107258020-A OR MX-362141-B OR AU-2020277220-A1 OR KR-20180081268-A OR JP-6067262-B2 OR CN-103531488-B OR US-20100051093-A1 OR BR-PI0612619-A2 OR KR-20180064194-A OR CN-101305300-A OR DE-112009001438-T5 OR MX-2007015993-A OR CN-112201731-A OR CN-114127961-A OR EP-4002495-A2 OR US-20190054506-A1 OR EP-3446777-A1 OR EP-3331032-A1 OR US-20180158977-A1 OR EP-1891468-A2 OR WO-2006134300-A2 OR JP-2008543712-A OR IL-188132-A OR US-20090266407-A1 OR EP-1890976-A2 OR WO-2006134301-A2 OR KR-20080017354-A OR EP-0002829-B1 OR CN-101296873-A OR KR-101995833-B1 OR KR-101333645-B1 OR KR-20080017350-A OR KR-20170074172-A OR CN-101296873-B).did.</p> <p>(Artificial Intelligence) Similar to:<br/>Unpublished Application #</p> <p>Text:<br/>(KR-20180058099-A OR CN-108110072-B OR JP-2017539093-A OR KR-20170074172-A OR JP-2017005253-A OR KR-20170097662-A OR JP-6411407-B2 OR CN-108963013-B OR KR-20180064194-A OR US-10763381-B2 OR KR-20180081268-A OR JP-2017525126-A OR TW-201618316-A OR KR-20160145484-A OR</p> | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO)) | OR | ON | ON | 2022/10/22 02:37 PM |
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|     |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                   |    |    |    |                        |
|-----|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|------------------------|
| L29 | 3485  | KR-101751727-B1 OR<br>CN-106898658-A OR<br>CN-108963013-A OR<br>EP-3373339-B1 OR<br>WO-2013161023-A1<br>OR CN-107258020-A<br>OR KR-101995833-B1<br>OR EP-3238271-A1 OR<br>WO-2016102471-A1<br>OR EP-3038164-A1 OR<br>CN-114127961-A OR<br>CN-106898658-B OR<br>EP-3373339-A1 OR<br>US-9577126-B2 OR<br>US-20180006164-A1<br>OR EP-3038164-B1 OR<br>US-20150380599-A1<br>OR US-20150083183-<br>A1 OR EP-3161879-A1<br>OR KR-20150000510-A<br>OR CN-104254922-A<br>OR JP-6552011-B2 OR<br>EP-4002495-A2 OR JP-<br>6453297-B2 OR EP-<br>3331032-A1 OR US-<br>20180158977-A1 OR<br>JP-2017118112-A OR<br>MX-362141-B OR AU-<br>2020277220-A1 OR<br>EP-3185307-B1 OR<br>EP-3185307-A1 OR<br>KR-20200090532-A OR<br>US-20190019904-A1<br>OR US-20170179325-<br>A1 OR US-<br>20160204301-A1 OR<br>JP-6746854-B2).did.<br>(((("SHANGHAI") near3<br>("JINKO") near3<br>("GREEN") near3<br>("ENERGY") near3<br>("ENTERPRISE") near3<br>("MANAGEMENT")<br>near3 ("CO") near3<br>("LTD")) OR<br>(("ZHEJIANG") near3<br>("JINKO") near3<br>("SOLAR") near3 ("CO")<br>near3<br>("LTD")))).AS,AANM. | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,<br>CZ, DD, DE, DK, EA,<br>EE, EP, ES, FI, FR, GB,<br>HR, HU, ID, IE, IL, IS,<br>IT, JP, KR, LT, LU, LV,<br>MA, MC, MD, MY, NL,<br>NO, NZ, OA, PH, PL,<br>PT, RO, RS, RU, SE,<br>SG, SI, SK, SU, TH,<br>TN, TR, TW, UA, VN,<br>WO); FPRS; EPO;<br>JPO; DERWENT;<br>IBM_TDB) | OR | ON | ON | 2022/12/15<br>12:43 PM |
| L30 | 39923 | (((("YU") near3 ("Kun"))<br>OR ("LIU") near3<br>("Changming")) OR<br>("ZHANG") near3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | (US-PGPUB; USPAT;<br>USOCR; FIT (AP, AT,<br>AU, BE, BG, BR, BY,<br>CA, CH, CN, CS, CU,                                                                                                                                                                                                                                                                            | OR | ON | ON | 2022/12/15<br>12:43 PM |

|     |        |                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                      |    |    |    |                     |
|-----|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|---------------------|
|     |        | ("Xinyu"))).INV.                                                                                                                                                            | CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)                                                                               |    |    |    |                     |
| L31 | 37361  | H01L31/02366,03685,068,1824,1868.cpc.                                                                                                                                       | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB) | OR | ON | ON | 2022/12/15 12:43 PM |
| L32 | 289    | (L29 L30) AND L31                                                                                                                                                           | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB) | OR | ON | ON | 2022/12/15 12:45 PM |
| L33 | 286823 | (semi\$1conduct\$4 Si silicon) near2 (support substrate structure layer film) WITH (textur\$4 uneven\$4 convex\$4 concav\$4 irregularit\$4 corrugat\$4 roughness curvature) | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN,                                        | OR | ON | ON | 2022/12/15 12:45 PM |

|     |      |                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                |    |    |    |                     |
|-----|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|---------------------|
| L34 | 7907 | H01L31/02366,03685,068,1824,1868.cpc. AND L33                                                                                                                                                                                                                 | WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)<br>(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB) | OR | ON | ON | 2022/12/15 12:45 PM |
| L35 | 312  | H01L31/02366,03685,068,1824,1868.cpc. AND (semi\$1conduct\$4 Si silicon) near2 (support substrate structure layer film) WITH (textur\$4 uneven\$4 convex\$4 concav\$4 irregularit\$4 corrugat\$4 roughness curvature) WITH (poly\$1gonal trapezoid\$4 square) | (US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)                                           | OR | ON | ON | 2022/12/15 12:45 PM |

#### PE2E SEARCH - Search History (Interference)

There are no Interference searches to show.



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| APPLICATION NO.      | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|----------------------|-------------|----------------------|---------------------|------------------|
| 17/964,190           | 10/12/2022  | Kun YU               | 084546-000044USD1   | 7994             |
| 22204                | 7590        | 11/29/2022           | EXAMINER            |                  |
| NIXON PEABODY, LLP   |             |                      | CENTRAL, DOCKET     |                  |
| 799 Ninth Street, NW |             |                      |                     |                  |
| SUITE 500            |             |                      |                     |                  |
| WASHINGTON, DC 20001 |             |                      |                     |                  |
|                      |             |                      | ART UNIT            | PAPER NUMBER     |
|                      |             |                      | OPAP                |                  |
|                      |             |                      | NOTIFICATION DATE   | DELIVERY MODE    |
|                      |             |                      | 11/29/2022          | ELECTRONIC       |

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipairlink@nixonpeabody.com  
nppatent@nixonpeabody.com



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United States Patent and Trademark Office  
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[www.uspto.gov](http://www.uspto.gov)

**In re Application of  
YU, KUN, et al.  
Application No.: 17/964,190  
Filed: 12 October 2022  
Attorney Docket No.: 084546-  
000044USD1  
For: SOLAR CELL,  
MANUFACTURING METHOD  
THEREOF, AND PHOTOVOLTAIC  
MODULE**

**: DECISION ON REQUEST TO  
: PARTICIPATE IN THE PATENT  
: PROSECUTION HIGHWAY  
: PROGRAM AND PETITION  
: TO MAKE SPECIAL UNDER  
: 37 CFR 1.102(a)**

This is a decision on the request to participate in the Patent Prosecution Highway (PPH) program and the petition under 37 CFR 1.102(a), filed October 26, 2022, to make the above-identified application special.

The request and petition under 37 C.F.R. § 1.102(a) are **GRANTED**. *It is noted that the PPH request lists the relied upon OEE work product as the decision to grant a patent. However, a decision to grant a patent cannot be the relied upon work product unless it was a first action allowance. Therefore, the decision herein is based on the Notice of Reason for Refusal dated August 02, 2022.*

**DISCUSSION**

A grantable request to participate in the PPH pilot program and petition to make special require:

1. The U.S. application for which participation in the Global/IP5 PPH pilot program is requested must have the same earliest date, whether this is the priority date or filing date, as that of a corresponding national or regional application filed with another Global/IP5 PPH participating office or a corresponding PCT international application for which one of the Global/IP5 PPH participating offices was the International Searching Authority (ISA) or the International Preliminary Examining Authority (IPEA).
2. Applicant must:

- a. Ensure all the claims in the U.S. application must sufficiently correspond or be amended to sufficiently correspond to the allowable/patentable claim(s) in the corresponding Office of Earlier Examination (OEE) application; and
  - b. Submit a claims correspondence table in English.
3. Examination of the U.S. application has not begun.
4. Applicant must submit:
  - a. Documentation of prior office action:
    - i. a copy of the office action(s) just prior to the “Decision to Grant a Patent” from each of the Global/IP5 PPH participating office application(s) containing the allowable/patentable claim(s) or
    - ii. if the allowable/patentable claims(s) are from a “Notification of Reasons for Refusal” then the Notification of Reasons for Refusal or
    - iii. if the Global/IP5 PPH participating office application is a first action allowance then no office action from the Global/IP5 PPH participating office is necessary should be indicated on the request/petition form or
    - iv. the latest work product in the international phase of the OEE PCT application; and
  - b. An English language translation of the Global/IP5 PPH participating office action or work product from (4)(a)(i)-(ii) or (iv) above.
5. Applicant must submit:
  - a. An IDS listing the documents cited by the Global/IP5 PPH participating office examiner in the Global/IP5 PPH participating office action or work product (unless already submitted in this application); and
  - b. Copies of the documents except U.S. patents or U.S. patent application publications (unless already submitted in this application).

The request to participate in the PPH pilot program and petition comply with the above requirements. Accordingly, the above-identified application has been accorded “special” status.

Telephone inquiries concerning this decision should be directed to Dale Hall at (571) 272-3586.

All other inquiries concerning the examination or status of the application is accessible in the PAIR system at <http://portal.uspto.gov>.

**/Dale A. Hall/  
Paralegal Specialist, OPET**



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| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 17/964,190         | 10/12/2022            | Kun YU                | 084546-000044USD1      |

**CONFIRMATION NO. 7994**

**NEW OR REVISED PPD NOTICE**

22204  
NIXON PEABODY, LLP  
799 Ninth Street, NW  
SUITE 500  
WASHINGTON, DC 20001



## NOTICE OF NEW OR REVISED PROJECTED PUBLICATION DATE

The above-identified application has a new or revised projected publication date. The current projected publication date for this application is 02/09/2023. If this is a new projected publication date (there was no previous projected publication date), the application has been cleared by Licensing & Review or a secrecy order has been rescinded and the application is now in the publication queue.

If this is a revised projected publication date (one that is different from a previously communicated projected publication date), the publication date has been revised due to processing delays in the USPTO or the abandonment and subsequent revival of an application. The application is anticipated to be published on a date that is more than six weeks different from the originally-projected publication date.

More detailed publication information is available through the private side of Patent Application Information Retrieval (PAIR) System. The direct link to access PAIR is currently <http://pair.uspto.gov>. Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Questions relating to this Notice should be directed to the Office of Data Management, Application Assistance Unit at (571) 272-4000, or (571) 272-4200, or 1-888-786-0101.

| <b>REQUEST FOR PARTICIPATION IN THE GLOBAL/IP5<br/>PATENT PROSECUTION HIGHWAY (PPH) PILOT PROGRAM IN THE USPTO</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                   |                       |                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-----------------------|-------------------|
| Application No.:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 17/964,190                                                        | First Named Inventor: | Kun YU            |
| Filing Date:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | October 12, 2022                                                  | Attorney Docket No.:  | 084546-000044USD1 |
| Title of Invention:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                       |                   |
| <b>THIS REQUEST FOR PARTICIPATION IN THE PPH PILOT PROGRAM ALONG WITH THE REQUIRED DOCUMENTS MUST BE SUBMITTED VIA THE USPTO PATENT ELECTRONIC FILING SYSTEM (EFS-WEB OR PATENT CENTER). INFORMATION REGARDING THE PATENT ELECTRONIC FILING SYSTEM IS AVAILABLE AT <a href="https://www.uspto.gov/efc">https://www.uspto.gov/efc</a></b>                                                                                                                                                                                                                                                                     |                                                                   |                       |                   |
| <b>APPLICANT HEREBY REQUESTS PARTICIPATION IN THE PATENT PROSECUTION HIGHWAY (PPH) PILOT PROGRAM AND PETITIONS TO MAKE THE ABOVE-IDENTIFIED APPLICATION SPECIAL UNDER THE PPH PILOT PROGRAM.</b>                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                   |                       |                   |
| <i><b>For national stage applications under 35 U.S.C. 371 only:</b> This is an express request to begin national stage processing under 35 U.S.C. 371(f). <b>Note:</b> National stage processing will not commence prior to 30 months from the priority date absent an express request to begin national stage processing under 35 U.S.C. 371(f) and fulfillment of the requirements under 35 U.S.C. 371(c)(1), (2), and (4) for payment of the basic national fee, copy of the International Application and English translation thereof (if required), and the oath or declaration of the inventor(s).</i> |                                                                   |                       |                   |
| <b>Office of earlier examination (OEE):</b> Japan (Japan Patent Office)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                   |                       |                   |
| <b>OEE application number:</b> 2022-084397                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                   |                       |                   |
| <b>Both the OEE application and the above-identified U.S. application have the following earliest date (filing or priority date):</b> August 4, 2021                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                   |                       |                   |
| <b>Type of OEE work product relied upon:</b> Decision to grant a patent                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                   |                       |                   |
| <b>Mailing date of OEE work product:</b> October 11, 2022                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                   |                       |                   |
| <b>Supporting Documents</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                       |                   |
| <b>1. OEE Work Product and Translation</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                   |                       |                   |
| A copy of the OEE work product and translation if not already in English:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                   |                       |                   |
| <input checked="" type="checkbox"/> Attached <input type="checkbox"/> Previously Submitted <input type="checkbox"/> Not required because the decision to grant a patent was the first office action                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                   |                       |                   |
| <input type="checkbox"/> Applicant requests the USPTO to attempt to obtain the OEE work product from the Dossier Access System or PATENTSCOPE                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                   |                       |                   |
| <small>NOTE: If the applicant requests the USPTO to obtain the OEE work product electronically and such attempt is unsuccessful, the applicant will be required to supply the document. Accordingly, to avoid dismissal of the initial PPH request and potential denial of participation in the PPH program, the applicant should verify that the OEE work product is actually available via the Dossier Access System or PATENTSCOPE before requesting retrieval. If the applicant is unable to verify availability, then the applicant should submit the document with the PPH request.</small>            |                                                                   |                       |                   |
| <b>2. References Cited in OEE Work Product</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                   |                       |                   |
| An information disclosure statement (IDS) listing the references cited in the OEE work product and document copies (except U.S. patents and U.S. published patent applications):                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                   |                       |                   |
| <input type="checkbox"/> Attached <input checked="" type="checkbox"/> Previously Submitted <input type="checkbox"/> Not required because no references were cited in the OEE work product                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                   |                       |                   |

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**REQUEST FOR PARTICIPATION IN THE GLOBAL/IP5 PPH PILOT PROGRAM IN THE USPTO**  
(continued)

|                  |            |                       |        |
|------------------|------------|-----------------------|--------|
| Application No.: | 17/964,190 | First Named Inventor: | Kun YU |
|------------------|------------|-----------------------|--------|

**3. Claims Correspondence Certification Statement**

All of the claims in this application sufficiently correspond to the patentable/allowable claims in the OEE application.

**4. Claims Correspondence Table**

| Claims in U.S. Application | Patentable/Allowable Claims in OEE Application | Explanation Regarding the Correspondence                                      |
|----------------------------|------------------------------------------------|-------------------------------------------------------------------------------|
| 1                          | 1                                              | Claim 1 sufficiently corresponds to claim 1 in OEE application                |
| 2                          | 2                                              | Claim 2 sufficiently corresponds to claim 2 in OEE application                |
| 3                          | 3                                              | Claim 3 sufficiently corresponds to claim 3 in OEE application                |
| 4                          | 4                                              | Claim 4 sufficiently corresponds to claim 4 in OEE application                |
| 5                          | 5                                              | Claim 5 sufficiently corresponds to claim 5 in OEE application                |
| 6                          | 6                                              | Claim 6 sufficiently corresponds to claim 6 in OEE application                |
| 7                          | 7                                              | Claim 7 sufficiently corresponds to claim 7 in OEE application                |
| 9                          | 8                                              | Claim 9 sufficiently corresponds to claim 8 in OEE application                |
| 11                         | 9                                              | Claim 11 sufficiently corresponds to claim 9 in OEE application               |
| 12                         | 10                                             | Claim 12 sufficiently corresponds to claim 10 in OEE application              |
| 14                         | 11                                             | Claim 14 sufficiently corresponds to claim 11 in OEE application              |
| 18                         | 12                                             | Claim 18 sufficiently corresponds to claim 12 in OEE application              |
| 20                         | 1, 13                                          | Claim 20 sufficiently corresponds to claims 1 and 13 in OEE application       |
| 21                         | 1, 2, 13                                       | Claim 21 sufficiently corresponds to claims 1, 2 and 13 in OEE application    |
| 22                         | 1, 3, 13                                       | Claim 22 sufficiently corresponds to claims 1, 3 and 13 in OEE application    |
| 23                         | 1, 4, 13                                       | Claim 23 sufficiently corresponds to claims 1, 4 and 13 in OEE application    |
| 24                         | 1, 5, 13                                       | Claim 24 sufficiently corresponds to claims 1, 5 and 13 in OEE application    |
| 25                         | 1, 5, 6, 13                                    | Claim 25 sufficiently corresponds to claims 1, 5, 6 and 13 in OEE application |
| 26                         | 1, 7, 13                                       | Claim 26 sufficiently corresponds to claims 1, 7 and 13 in OEE application    |
| 27                         | 1, 8, 13                                       | Claim 27 sufficiently corresponds to claims 1, 8 and 13 in OEE application    |
|                            |                                                |                                                                               |
|                            |                                                |                                                                               |
|                            |                                                |                                                                               |
|                            |                                                |                                                                               |

|                      |                                |                     |                  |
|----------------------|--------------------------------|---------------------|------------------|
| Signature            | /Sumiyo Onda, Reg. No. 62,166/ | Date                | October 26, 2022 |
| Name (print or type) | Sumiyo Onda                    | Registration Number | 62,166           |

## Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. The United States Patent and Trademark Office (USPTO) collects the information in this record under authority of 35 U.S.C. 2. The USPTO's system of records is used to manage all applicant and owner information including name, citizenship, residence, post office address and other information with respect to inventors and their legal representatives pertaining to the applicant's/owner's activities in connection with the invention for which a patent is sought or has been granted. The applicable Privacy Act System of Records Notice for this information is COMMERCE/PAT-TM-7 Patent Application Files, available in the Federal Register at 78 FR 19243 (March 29, 2013) (<https://www.govinfo.gov/content/pkg/FR-2013-03-29/pdf/2013-07341.pdf>).

Routine uses of this information may include disclosure to the following: to law enforcement and investigation in the event that the system of records indicates a violation or potential violation of law; to a Federal, state, local, or international agency, in response to its request; to an agency, organization, or individual for the purpose of performing audit or oversight operations as authorized by law; to non-federal personnel under contract to the agency; to a court for adjudication and litigation; to the Department of Justice for Freedom of Information Act (FOIA) assistance; to Members of Congress submitting a request involving an individual to whom the record pertains, when the individual has requested the Member's assistance with respect to the subject matter of the record; to the Office of Personnel Management (OPM) for personnel research purposes; to National Archives and Records Administration for inspection of records; and to the Office of Management and Budget (OMB) for legislative coordination and clearance. Failure to provide any part of the requested information may result in an inability to process requests for access and information.

## CLAIMS

What is claimed is:

1. A solar cell, comprising:

- 5 a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure has a non-pyramid-shaped microstructure and includes two or more first substructures at least partially stacked on one another, a top surface of the first substructure is a polygonal plane, and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ; and wherein a front surface of the semiconductor substrate has a second texture structure, the second texture structure includes
- 10 a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ ;
- 15 a first passivation layer located on the second texture structure of the front surface of the semiconductor substrate;
- a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;
- a doped conductive layer located on a surface of the tunnel oxide layer; and
- 20 a second passivation layer located on a surface of the doped conductive layer.

2. The solar cell according to claim 1, wherein for the two or more first substructures at least partially stacked on one another, in the direction away from the rear surface and perpendicular to the rear surface, a distance between the top surface of the outermost first substructure and the top surface of the adjacent first substructure is equal to or less than 2 $\mu\text{m}$ .

25 3. The solar cell according to claim 1, wherein a shape of the polygonal plane includes at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square or a substantially trapezoid.

4. The solar cell according to claim 1, wherein a thickness of the tunnel oxide layer on the

top surface of the outermost first substructure is less than a thickness of the tunnel oxide layer on a side surface of the outermost first substructure.

5        5. The solar cell according to claim 1, wherein the first texture structure further includes two or more adjacent second substructures that do not stacked on one another, and a one-dimensional size of a top surface of the second substructure away from the rear surface is less than or equal to 45  $\mu\text{m}$ .

6. The solar cell according to claim 5, wherein the top surface of the second substructure is a polygonal plane.

10        7. The solar cell according to claim 1, wherein the tunnel oxide layer includes at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer, and the tunnel oxide layer has a thickness ranging from 0.8 nm to 2 nm.

15        8. The solar cell according to claim 1, wherein the second passivation layer includes at least one of a silicon nitride layer, a silicon oxide layer or a silicon oxynitride layer, and the second passivation layer has a thickness ranging from 70 nm to 120 nm.

9. The solar cell according to claim 1, wherein the first passivation layer includes at least one of a silicon oxide layer, a silicon nitride layer, an aluminum oxide layer or a silicon oxynitride layer.

20        10. The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer and a silicon nitride layer, the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, and the silicon nitride layer has a thickness ranging from 50 nm to 110 nm.

25        11. The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer, a silicon nitride layer and a silicon oxynitride layer sequentially stacked, the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, the silicon nitride layer has a thickness ranging from 40 nm to 80 nm, and the silicon oxynitride layer has a thickness ranging from 10 nm to 60 nm.

30        12. The solar cell according to claim 1, wherein the semiconductor substrate is an N-type monocrystalline silicon substrate, the doped conductive layer is an N-type doped polycrystalline silicon layer, an N-type doped microcrystalline silicon layer or an N-type doped

amorphous silicon layer, and the doped conductive layer has a thickness ranging from 60 nm to 200 nm.

13. A photovoltaic module, comprising a plurality of solar cell strings, wherein each of the plurality of solar cell strings comprises solar cells according to any one of claims 1-12.

【書類名】 手続補正書  
 【整理番号】 06989JP02  
 【提出日】 令和 4年 9月 9日  
 【あて先】 特許庁長官殿  
 【事件の表示】  
     【出願番号】 特願2022- 84397  
 【補正をする者】  
     【識別番号】 521376620  
     【氏名又は名称】 上海晶科緑能企業管理有限公司  
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 【代理人】  
     【識別番号】 110000671  
     【氏名又は名称】 八田国際特許業務法人  
     【代表者】 荒木 一秀  
     【電話番号】 03-3230-4766

【手続補正1】

【補正対象書類名】 特許請求の範囲  
 【補正対象項目名】 全文  
 【補正方法】 変更  
 【補正の内容】

【書類名】 特許請求の範囲

【請求項 1】

後面に第 1 テクスチャ構造、前面に第 2 テクスチャ構造を有する半導体基板と、  
 前記半導体基板の前面における第 2 テクスチャ構造上に位置する第 1 パッシベーション層と、

前記半導体基板の後面における第 1 テクスチャ構造上に位置するトンネル酸化層と、  
 前記トンネル酸化層の表面に位置するドーパ導電層と、  
 前記ドーパ導電層の表面に位置する第 2 パッシベーション層と、を含む太陽電池であって、

前記第 1 テクスチャ構造は、非ピラミッド状の微構造形状を呈し、少なくとも部分的に積み重ねられた 2 つ又は複数の第 1 サブ構造を含み、

前記第 1 サブ構造の頂部表面は、多角形平面であり、

前記少なくとも部分的に積み重ねられた 2 つ又は複数の第 1 サブ構造のうち、最外側の第 1 サブ構造の頂部表面の 1 次元寸法が  $4.5 \mu\text{m}$  以下であり、

前記第 2 テクスチャ構造は、ピラミッド状の微構造を含み、

前記ピラミッド状の微構造は、前記半導体基板の前面から遠く離れる頂部と、前記半導体基板の前面に近づく底部とを有し、

前記前面から遠く離れ且つ前記前面に垂直である方向において、前記ピラミッド状の微構造の頂部と底部との距離が  $5 \mu\text{m}$  以下である、ことを特徴とする太陽電池。

【請求項 2】

前記少なくとも部分的に積み重ねられた 2 つ又は複数の第 1 サブ構造は、前記後面から遠く離れ且つ前記後面に垂直である方向において、最外側の第 1 サブ構造の頂部表面とそれに隣接する第 1 サブ構造の頂部表面との距離が  $2 \mu\text{m}$  以下である、請求項 1 に記載の太陽電池。

【請求項 3】

前記第 1 サブ構造の頂部表面は、菱形、方形、台形、略菱形、略方形、略台形のうちの少なくとも 1 つである、請求項 1 に記載の太陽電池。

【請求項 4】

前記最外側の第1サブ構造の頂部表面上のトンネル酸化層の厚さは、前記最外側の第1サブ構造の側部表面上のトンネル酸化層の厚さよりも小さい、請求項1に記載の太陽電池。

【請求項5】

前記第1テクスチャ構造は、さらに互いに積み重ねられずに隣接して配列される2つ又は複数の第2サブ構造を含み、前記後面から遠く離れる前記第2サブ構造の頂部表面の1次元寸法は、 $45\mu\text{m}$ 以下である、請求項1に記載の太陽電池。

【請求項6】

前記第2サブ構造の頂部表面は、多角形平面である、請求項5に記載の太陽電池。

【請求項7】

前記トンネル酸化層は、酸化シリコン層、酸化アルミニウム層、酸窒化シリコン層、酸化モリブデン層、及び酸化ハフニウム層のうちの少なくとも1つを含み、

前記トンネル酸化層の厚さは、 $0.8\text{nm}$ ～ $2\text{nm}$ である、請求項1に記載の太陽電池。

【請求項8】

前記第2パッシベーション層は、窒化シリコン層、酸化シリコン層、酸窒化シリコン層のうちの少なくとも1つを含み、

前記第2パッシベーション層の厚さは、 $70\text{nm}$ ～ $120\text{nm}$ である、請求項1に記載の太陽電池。

【請求項9】

前記第1パッシベーション層は、酸化シリコン層、窒化シリコン層、酸化アルミニウム層、酸窒化シリコン層のうちの少なくとも1つを含む、請求項1に記載の太陽電池。

【請求項10】

前記第1パッシベーション層は、酸化アルミニウム層と窒化シリコン層との積層パッシベーション構造であり、

前記酸化アルミニウム層の厚さは $2\text{nm}$ ～ $10\text{nm}$ であり、前記窒化シリコン層の厚さは $50\text{nm}$ ～ $110\text{nm}$ である、請求項1に記載の太陽電池。

【請求項11】

前記第1パッシベーション層は、順に積層設置された酸化アルミニウム層、窒化シリコン層及び酸窒化シリコン層の積層パッシベーション構造であり、

前記酸化アルミニウム層の厚さ範囲は $2\text{nm}$ ～ $10\text{nm}$ であり、前記窒化シリコン層の厚さ範囲は $40\text{nm}$ ～ $80\text{nm}$ であり、前記酸窒化シリコン層の厚さ範囲は $10\text{nm}$ ～ $60\text{nm}$ である、請求項1に記載の太陽電池。

【請求項12】

前記半導体基板は、N型単結晶シリコン基板であり、

前記ドーパ導電層は、N型ドーパ多結晶シリコン層、N型ドーパ微結晶シリコン層、又はN型ドーパアモルファスシリコン層であり、

前記ドーパ導電層の厚さは、 $60\text{nm}$ ～ $200\text{nm}$ である、請求項1に記載の太陽電池。

【請求項13】

請求項1～12のいずれか1項に記載の太陽電池を含む太陽電池ストリングを複数備える太陽電池モジュール。

## Notice of Reasons for Refusal

|                           |                                                 |                 |
|---------------------------|-------------------------------------------------|-----------------|
| Patent application number | Japanese Patent Application                     | No. 2022-084397 |
| Draft date                | July 25, 4th year of Reiwa                      |                 |
| JPO Examiner              | Toshifumi Hara                                  | 4078 2K00       |
| Patent applicant agent    | Hatta International Patent Business Corporation |                 |
| Applicable Article        | Article 36, Paragraph 6, Item 2 (Clarity)       |                 |

This application should be rejected for the following reasons: If you have any comments on this, please submit your comments within 3 months from the date this notice was sent.

### Reasons

1. (Clarity) This application does not meet the requirements stipulated in Article 36, Paragraph 6, Item 2 of the Patent Act in the following points.

#### ● Reason 1 (Clarity)

##### Claims 1-13

According to claim 1, “a first passivation layer located the second texture structure” does not clearly describes how the first passivation layer is located relative to the second texture structure. As a result, the relationship between the second texture structure and the first passivation layer is not clear. (If it is “a first passivation layer located on the second texture structure”, the relationship will be clear). Thus, it is possible to clearly describe the invention according to claim 1

Therefore, claim 1 is not clear.

Claims 2-13 are objected due to their dependencies from claim 1.

##### Claims 11, 13

Claim 11 recites “silicon oxynitride”, but does not recite “silicon oxynitride layer”. It is not clear whether the silicon nitride itself forms a layer, so what “the silicon oxynitride layer” refers to is not clear.

Therefore, claim 11 is not clear.

Claim 13 is objected due to its dependency from claim 11.

## &lt;List of cited references&gt;

## 1. 1. International Publication No. 2016/129481

-----  
<Record of prior art literature search  
results>

- Surveyed field    IPC        H01L31 / 02-31 / 078  
                                         H01L31 / 18-31 / 20

## Reference cited

International Patent Application No. 2016/129481

US Patent Application Publication No. 2018/018295

US Patent Application Publication No. 2018/0315866

JP-A-2012-216788

Chinese Patent Application Publication No. 112599615

Chinese Patent Application Publication No. 110931596

JP-Laid open 6-61515

The record of the results of this prior art literature search does not constitute a reason for refusal.

If you have any inquiries regarding the content of this notice of reasons for refusal or if you would like to have an interview, please contact us at the following contact information. If you would like to send the amendment proposal by e-mail etc., please let us know by phone.

Judging Part 1 (PA2K)  
TEL. 03-3581-1101

Optical Device  
extension 3253

Toshifumi Hara

## 拒絶理由通知書

|          |                        |
|----------|------------------------|
| 特許出願の番号  | 特願 2022-084397         |
| 起案日      | 令和 4年 7月 25日           |
| 特許庁審査官   | 原 俊文 4078 2K00         |
| 特許出願人代理人 | 八田国際特許業務法人 様           |
| 適用条文     | 第 36 条第 6 項第 2 号 (明確性) |

この出願は、次の理由によって拒絶をすべきものです。これについて意見がありましたら、この通知書の発送の日から 3 か月以内に意見書を提出してください。

### 理由

1. (明確性) この出願は、特許請求の範囲の記載が下記の点で、特許法第 36 条第 6 項第 2 号に規定する要件を満たしていない。

### 記

#### ●理由 1 (明確性) について

##### ・請求項 1-13

請求項 1 の「第 2 テクスチャ構造に位置する第 1 パッシベーション層」という記載は、第 1 パッシベーション層が第 2 テクスチャ構造に対してどのように位置するものであるのかについて不明瞭であり、その結果、第 2 テクスチャ構造と第 1 パッシベーション層との構造的関係が不明確である（「第 2 テクスチャ構造上に位置する第 1 パッシベーション層」という意味であれば、そのように明確に記載されたい。）。したがって、請求項 1 の記載から発明を明確に把握することができない。

よって、請求項 1 に係る発明は明確でない。

請求項 1 を引用する請求項 2-13 に係る発明についても同様である。

##### ・請求項 11, 13

請求項 11 において、「前記酸化シリコン層」という記載より前に、「酸化シリコン」は記載されているが「酸化シリコン層」は記載されておらず、「酸化シリコン」自体が層を形成していることが明らかともいえないから、「前記酸化シリコン層」という記載が指すものが不明確である。

よって、請求項 1 1 に係る発明は明確でない。

請求項 1 1 を引用する請求項 1 3 に係る発明についても同様である。

-----  
<先行技術文献調査結果の記録>

- ・調査した分野     I P C   H 0 1 L 3 1 / 0 2 - 3 1 / 0 7 8  
                             H 0 1 L 3 1 / 1 8 - 3 1 / 2 0
- ・先行技術文献     国際公開第 2 0 1 6 / 1 2 9 4 8 1 号  
                             米国特許出願公開第 2 0 1 8 / 0 1 8 2 9 0 5 号明細書  
                             米国特許出願公開第 2 0 1 8 / 0 3 1 5 8 6 6 号明細書  
                             特開 2 0 1 2 - 2 1 6 7 8 8 号公報  
                             中国特許出願公開第 1 1 2 5 9 9 6 1 5 号明細書  
                             中国特許出願公開第 1 1 0 9 3 1 5 9 6 号明細書  
                             特開平 6 - 6 1 5 1 5 号公報

この先行技術文献調査結果の記録は拒絶理由を構成するものではありません。

この拒絶理由通知の内容に関するお問合せ又は面接のご希望がありましたら、次の連絡先までご連絡ください。電子メール等で補正案等の送付を希望される場合は、その旨を電話でお知らせください。

審査第一部光デバイス (PA2K)    原   俊文 (はら   としふみ)  
T E L .   0 3 - 3 5 8 1 - 1 1 0 1    内線 3 2 5 3

## Notice of Allowance

|                           |                                                                                 |                 |
|---------------------------|---------------------------------------------------------------------------------|-----------------|
| Patent application number | Japanese Patent Application                                                     | No. 2022-084397 |
| Draft date                | September 30, 4 <sup>th</sup> year of Reiwa                                     |                 |
| JPO Examiner              | Toshifumi Hara                                                                  | 4078      2K00  |
| Title of the invention    | SOLAR CELL, MANUFACTURING METHOD<br>THEREOF, AND PHOTOVOLTAIC MODULE            |                 |
| Number of claims          | 13                                                                              |                 |
| Patent applicant          | SHANGHAI JINKO GREEN ENERGY ENTERPRISE<br>MANAGEMENT CO., LTD. (1 other person) |                 |
| Agent                     | Hatta International Patent Business Corporation                                 |                 |

We will grant a patent for this application because we will not find the reason for refusal.

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It certifies that the above is not different from what is recorded in the file.

Certification date      October 4<sup>th</sup>, 4<sup>th</sup> year of Reiwa

Minister of Economy, Trade and Industry      Takashi Sato

Note: The patent fee must be paid within 30 days from the date of receipt of this document.

- Application type      Normal
- References      Available
- Article 30 of the Patent Law      None
- Change in the name of the invention      None
  
- Fungus deposit

## Reference Information

Patent application number Japanese Patent Application No. 2022-084397

▪ FI

|      |       |     |   |
|------|-------|-----|---|
| H01L | 31/04 | 280 | , |
| H01L | 31/06 | 400 | , |
| H01L | 31/04 | 240 |   |

▪ Surveyed fields (IPC, DB name)

|      |                  |
|------|------------------|
| H01L | 31 / 02-31 / 078 |
| H01L | 31 / 18-31 / 20  |

▪ Reference patent documents

|                                                       |          |
|-------------------------------------------------------|----------|
| International Publication No. 2016/129481             | (WO, A1) |
| US Patent Application Publication No. 2018/018295     | (US, A1) |
| US Patent Application Publication No. 2018/0315866    | (US, A1) |
| Japanese Patent Application Laid-Open No. 2012-216788 | (JP, A)  |
| Chinese Patent Application Publication No. 112599615  | (CN, A)  |
| Japanese Patent Application Laid-Open No. 06-061515   | (JP, A)  |

▪ Reference book magazine

特許査定  
(分割)

|         |                          |
|---------|--------------------------|
| 特許出願の番号 | 特願 2 0 2 2 - 0 8 4 3 9 7 |
| 起案日     | 令和 4 年 9 月 3 0 日         |
| 特許庁審査官  | 原 俊文 4 0 7 8 2 K 0 0     |
| 発明の名称   | 太陽電池及びその製造方法、太陽電池モジュール   |
| 請求項の数   | 1 3                      |
| 特許出願人   | 上海晶科緑能企業管理有限公司（ほか 1 名）   |
| 代理人     | 八田国際特許業務法人               |

この出願については、拒絶の理由を発見しないから、特許査定をします。

---

上記はファイルに記録されている事項と相違ないことを認証する。

認証日 令和 4年10月 4日 経済産業事務官 佐藤 隆

注意：この書面を受け取った日から 3 0 日以内に特許料の納付が必要です。

- ・出願種別 分割
- ・参考文献 有
- ・特許法第30条適用 無
- ・発明の名称の変更 無

- ・菌寄託

## 参考情報

特許出願の番号 特願2022-084397

### ・ F I

|      |       |     |   |
|------|-------|-----|---|
| H01L | 31/04 | 280 | , |
| H01L | 31/06 | 300 | , |
| H01L | 31/04 | 240 |   |

### ・ 調査した分野 (IPC, DB名)

|      |              |
|------|--------------|
| H01L | 31/02-31/078 |
| H01L | 31/18-31/20  |

### ・ 参考特許文献

|                       |          |
|-----------------------|----------|
| 国際公開第2016/129481      | (WO, A1) |
| 米国特許出願公開第2018/0182905 | (US, A1) |
| 米国特許出願公開第2018/0315866 | (US, A1) |
| 特開2012-216788         | (JP, A)  |
| 中国特許出願公開第112599615    | (CN, A)  |
| 中国特許出願公開第110931596    | (CN, A)  |
| 特開平06-061515          | (JP, A)  |

### ・ 参考図書雑誌



UNITED STATES  
PATENT AND TRADEMARK OFFICE

P.O. Box 1450  
Alexandria, VA 22313 - 1450  
www.uspto.gov

## ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #  
**17/964,190**

RECEIPT DATE / TIME  
**10/26/2022 10:57:30 AM ET**

ATTORNEY DOCKET #  
**084546-000044USD1**

### Title of Invention

SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE

### Application Information

APPLICATION TYPE Utility - Nonprovisional Application  
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 7994

FILED BY Donald Sias

PATENT CENTER # 61107095

FILING DATE 10/12/2022

CUSTOMER # 22204

FIRST NAMED INVENTOR Kun YU

CORRESPONDENCE ADDRESS -

AUTHORIZED BY Sumiyo Onda

### Documents

**TOTAL DOCUMENTS: 5**

| DOCUMENT                                             | PAGES | DESCRIPTION                                               | SIZE (KB) |
|------------------------------------------------------|-------|-----------------------------------------------------------|-----------|
| 084546_000044USD1_PPH.pdf                            | 3     | Petition to make Special under Patent Prosecution Highway | 1039 KB   |
| 084546_000044USD1_preliminary_amendment_with_PPH.pdf | 7     | Petition to make Special under Patent Prosecution Highway | 107 KB    |
| Notice_of_Reasons_for_Refusal.pdf                    | 4     | Petition to make Special under Patent Prosecution Highway | 304 KB    |
| PPH_Granted_Claims.pdf                               | 5     | Claims                                                    | 352 KB    |
| PPH_Notice_of-Allowance.pdf                          | 6     | Petition to make Special under Patent Prosecution Highway | 286 KB    |

## Digest

| DOCUMENT                                                | MESSAGE DIGEST(SHA-512)                                                                                                                  |
|---------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| 084546_000044USD1_PPH.pdf                               | AA0FAB89EA9C1571DB800A269BCFD200A1C1DAC7956AF766<br>A04CFFEE4EE6F49DF6E7DEA4FBC6B0CBA5F1B733AC7129B3<br>C44A70FE377090DDF860BD4E9397B0D6 |
| 084546_000044USD1_preliminary__amendment__with__PPH.pdf | 67C4F1E7D1970C76963AD4A325CEACD5B7902F527D06707CF<br>F49042A0F178B14C6917D60EA1BA083AAA30E20553FB60FEB<br>B6388DC0542710738CDA973254CE0E |
| Notice_of_Reasons_for_Refusal.pdf                       | BAC8574FEFD0041D8DF29138FCD7D1E58FD8A032863C5261E<br>BAA2BBBFD2437F6D670BCC0ACF283A740560CBD8495C0B78<br>97C86B083DEA9E5A3A2A5C56B656705 |
| PPH_Granted_Claims.pdf                                  | 25B1CA8ABD9B7AF38E79FE672E4CCF12020528612FB88EA2B<br>CDF3599A85B81D182C992E518F179E4C34E59E5637B467DC5<br>A08B3E27EC34806C973B161889B0D9 |
| PPH_Notice_of_Allowance.pdf                             | 889847B88AE2EEBFA15AB060F8B823F42B84E8FAC87136FF5<br>755396ACBC9DC40A1E3E28DF84CB2DD20BA1AF855B1C4AE<br>B20A6F238CF8B1B6D1D478D050F11DDA |

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

### New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

### National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

### New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

|                                |   |                        |
|--------------------------------|---|------------------------|
| In re Patent Application       | ) |                        |
| Kun YU                         | ) |                        |
| Application No.: 17/964,190    | ) |                        |
| Filed: October 12, 2022        | ) |                        |
| For: SOLAR CELL, MANUFACTURING | ) | Confirmation No.: 7994 |
| METHOD THEREOF, AND            | ) |                        |
| PHOTOVOLTAIC MODULE            | ) |                        |

**PRELIMINARY AMENDMENT**

**Mail Stop Petition – Via EFS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Sir:

Prior to the examination of this application, please amend the subject application as follows:

**Amendments to the Claims** begin on **page 2** of this paper.

**Remarks** begin on **page 7** of this paper.

**IN THE CLAIMS:**

Please amend the claims as follows:

1. (Original) A solar cell, comprising:

a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure has a non-pyramid-shaped microstructure and includes two or more first substructures at least partially stacked on one another, a top surface of the first substructure is a polygonal plane, and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ; and wherein a front surface of the semiconductor substrate has a second texture structure, the second texture structure includes a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ ;

a first passivation layer located on the second texture structure of the front surface of the semiconductor substrate;

a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;

a doped conductive layer located on a surface of the tunnel oxide layer; and

a second passivation layer located on a surface of the doped conductive layer.

2. (Original) The solar cell according to claim 1, wherein for the two or more first substructures at least partially stacked on one another, in the direction away from the rear surface and perpendicular to the rear surface, a distance between the top surface of the outermost first substructure and the top surface of the adjacent first substructure is equal to or less than 2  $\mu\text{m}$ .

3. (Original) The solar cell according to claim 1, wherein a shape of the polygonal plane includes at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square or a substantially trapezoid.

4. (Original) The solar cell according to claim 1, wherein a thickness of the tunnel oxide layer on the top surface of the outermost first substructure is less than a thickness of the tunnel oxide layer on a side surface of the outermost first substructure.

5. (Original) The solar cell according to claim 1, wherein the first texture structure further includes two or more adjacent second substructures that do not stacked on one another, and a one-dimensional size of a top surface of the second substructure away from the rear surface is less than or equal to 45  $\mu\text{m}$ .

6. (Original) The solar cell according to claim 5, wherein the top surface of the second substructure is a polygonal plane.

7. (Currently Amended) The solar cell according to claim 1, wherein the tunnel oxide layer includes at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer, and the tunnel oxide layer has a thickness ranging from 0.8 nm to 2 nm.

8. (Cancelled)

9. (Currently Amended) The solar cell according to claim 1, wherein the second passivation layer includes at least one of a silicon nitride layer, a silicon oxide layer or a silicon oxynitride layer, and the second passivation layer has a thickness ranging from 70 nm to 120 nm.

10 (Cancelled)

11. (Original) The solar cell according to claim 1, wherein the first passivation layer includes at least one of a silicon oxide layer, a silicon nitride layer, an aluminum oxide layer or a silicon oxynitride layer.

12. (Currently Amended) The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer and a silicon nitride layer, the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, and the silicon nitride layer has a thickness ranging from 50 nm to 110 nm.

13. (Cancelled)

14. (Currently Amended) The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer, a silicon nitride layer and a silicon oxynitride layer sequentially stacked, the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, the silicon nitride layer has a thickness ranging from 40 nm to 80 nm, and the silicon oxynitride layer has a thickness ranging from 10 nm to 60 nm.

15-17 (Cancelled)

18. (Currently Amended) The solar cell according to claim 1, wherein the semiconductor substrate is an N-type monocrystalline silicon substrate, the doped conductive layer is an N-type doped polycrystalline silicon layer, an N-type doped microcrystalline silicon layer or an N-type doped amorphous silicon layer, and the doped conductive layer has a thickness ranging from 60 nm to 200 nm.

19 (Cancelled)

20. (Original) A photovoltaic module, comprising a plurality of solar cell strings, wherein each of the plurality of solar cell strings comprises solar cells, and at least one of the solar cells comprises:

a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure has a non-pyramid-shaped microstructure and includes two or more first substructures at least partially stacked on one another, a top surface of the first substructure is a polygonal plane, and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ; and wherein a front surface of the semiconductor substrate has a second texture structure, the second texture structure includes a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ ;

a first passivation layer located on the second texture structure of the front surface of

the semiconductor substrate;

a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;

a doped conductive layer located on a surface of the tunnel oxide layer; and

a second passivation layer located on a surface of the doped conductive layer.

21. (New) The photovoltaic module according to claim 20, wherein for the two or more first substructures at least partially stacked on one another, in the direction away from the rear surface and perpendicular to the rear surface, a distance between the top surface of the outermost first substructure and the top surface of the adjacent first substructure is equal to or less than  $2\mu\text{m}$ .

22. (New) The photovoltaic module according to claim 20, wherein a shape of the polygonal plane includes at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square or a substantially trapezoid.

23. (New) The photovoltaic module according to claim 20, wherein a thickness of the tunnel oxide layer on the top surface of the outermost first substructure is less than a thickness of the tunnel oxide layer on a side surface of the outermost first substructure.

24. (New) The photovoltaic module according to claim 20, wherein the first texture structure further includes two or more adjacent second substructures that do not stacked on one another, and a one-dimensional size of a top surface of the second substructure away from the rear surface is less than or equal to  $45\mu\text{m}$ .

25. (New) The photovoltaic module according to claim 24, wherein the top surface of the second substructure is a polygonal plane.

26. (New) The photovoltaic module according to claim 20, wherein the tunnel oxide layer includes at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer, and the tunnel oxide layer has a thickness ranging from 0.8 nm to 2 nm.

27. (New) The photovoltaic module according to claim 20, wherein the second passivation layer includes at least one of a silicon nitride layer, a silicon oxide layer or a silicon oxynitride layer, and the second passivation layer has a thickness ranging from 70 nm to 120 nm.

**REMARKS**

Claims 1-7, 9, 11-12, 14, 18 and 20 are preliminary amended herein to be consistent with the allowed claims in the counterpart Japanese App. No. 2022-084397 for the purposes of PPH request being filed concurrently herewith. In addition, multiple dependency recited in claim 13 is expanded and now added as new claims 21-27. As a result, claims 8, 10, 13, 15-17 and 19 are canceled without prejudice or disclaimer. Applicant respectfully submits that no new matter is added. Examination on the merits is requested.

The Commissioner is hereby authorized to charge any fee required in connection with this filing, and any additional fees which may be required, or credit any overpayment to Deposit Account No. 19-2380.

Respectfully submitted,

/Sumiyo Onda, Reg. No. 62,166/  
Sumiyo Onda  
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UNITED STATES  
PATENT AND TRADEMARK OFFICE

P.O. Box 1450  
Alexandria, VA 22313 - 1450  
www.uspto.gov

## ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #  
**17/964,190**

RECEIPT DATE / TIME  
**10/26/2022 10:36:19 AM ET**

ATTORNEY DOCKET #  
**084546-000044USD1**

### Title of Invention

SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE

### Application Information

APPLICATION TYPE Utility - Nonprovisional Application  
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 7994

FILED BY Donald Sias

PATENT CENTER # 61106927

FILING DATE 10/12/2022

CUSTOMER # 22204

FIRST NAMED INVENTOR Kun YU

CORRESPONDENCE ADDRESS -

AUTHORIZED BY Sumiyo Onda

### Documents

**TOTAL DOCUMENTS: 2**

| DOCUMENT                                             | PAGES | DESCRIPTION                                               | SIZE (KB) |
|------------------------------------------------------|-------|-----------------------------------------------------------|-----------|
| 084546_000044USD1_PPH.pdf                            | 3     | Petition to make Special under Patent Prosecution Highway | 1039 KB   |
| 084546_000044USD1_preliminary_amendment_with_PPH.pdf | 7     | Petition to make Special under Patent Prosecution Highway | 107 KB    |

### Digest

| DOCUMENT                  | MESSAGE DIGEST(SHA-512)                          |
|---------------------------|--------------------------------------------------|
| 084546_000044USD1_PPH.pdf | AA0FAB89EA9C1571DB800A269BCFD200A1C1DAC7956AF766 |

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C44A70FE377090DDF860BD4E9397B0D6

084546\_000044USD1\_prelimin 67C4F1E7D1970C76963AD4A325CEACD5B7902F527D06707CF  
ary\_amendment\_with\_PPH.pdf F49042A0F178B14C6917D60EA1BA089AAA30E20559FB60FEB  
B6388DC0542710738CDA973254CE0E

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

#### **New Applications Under 35 U.S.C. 111**

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

#### **National Stage of an International Application under 35 U.S.C. 371**

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

#### **New International Application Filed with the USPTO as a Receiving Office**

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

|                                |   |                        |
|--------------------------------|---|------------------------|
| In re Patent Application       | ) |                        |
| Kun YU                         | ) |                        |
| Application No.: 17/964,190    | ) |                        |
| Filed: October 12, 2022        | ) |                        |
| For: SOLAR CELL, MANUFACTURING | ) | Confirmation No.: 7994 |
| METHOD THEREOF, AND            | ) |                        |
| PHOTOVOLTAIC MODULE            | ) |                        |

**PRELIMINARY AMENDMENT**

**Mail Stop Petition – Via EFS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Sir:

Prior to the examination of this application, please amend the subject application as follows:

**Amendments to the Claims** begin on **page 2** of this paper.

**Remarks** begin on **page 7** of this paper.

**IN THE CLAIMS:**

Please amend the claims as follows:

1. (Original) A solar cell, comprising:

a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure has a non-pyramid-shaped microstructure and includes two or more first substructures at least partially stacked on one another, a top surface of the first substructure is a polygonal plane, and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ; and wherein a front surface of the semiconductor substrate has a second texture structure, the second texture structure includes a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ ;

a first passivation layer located on the second texture structure of the front surface of the semiconductor substrate;

a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;

a doped conductive layer located on a surface of the tunnel oxide layer; and

a second passivation layer located on a surface of the doped conductive layer.

2. (Original) The solar cell according to claim 1, wherein for the two or more first substructures at least partially stacked on one another, in the direction away from the rear surface and perpendicular to the rear surface, a distance between the top surface of the outermost first substructure and the top surface of the adjacent first substructure is equal to or less than 2  $\mu\text{m}$ .

3. (Original) The solar cell according to claim 1, wherein a shape of the polygonal plane includes at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square or a substantially trapezoid.

4. (Original) The solar cell according to claim 1, wherein a thickness of the tunnel oxide layer on the top surface of the outermost first substructure is less than a thickness of the tunnel oxide layer on a side surface of the outermost first substructure.

5. (Original) The solar cell according to claim 1, wherein the first texture structure further includes two or more adjacent second substructures that do not stacked on one another, and a one-dimensional size of a top surface of the second substructure away from the rear surface is less than or equal to 45  $\mu\text{m}$ .

6. (Original) The solar cell according to claim 5, wherein the top surface of the second substructure is a polygonal plane.

7. (Currently Amended) The solar cell according to claim 1, wherein the tunnel oxide layer includes at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer, and the tunnel oxide layer has a thickness ranging from 0.8 nm to 2 nm.

8. (Cancelled)

9. (Currently Amended) The solar cell according to claim 1, wherein the second passivation layer includes at least one of a silicon nitride layer, a silicon oxide layer or a silicon oxynitride layer, and the second passivation layer has a thickness ranging from 70 nm to 120 nm.

10 (Cancelled)

11. (Original) The solar cell according to claim 1, wherein the first passivation layer includes at least one of a silicon oxide layer, a silicon nitride layer, an aluminum oxide layer or a silicon oxynitride layer.

12. (Currently Amended) The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer and a silicon nitride layer, the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, and the silicon nitride layer has a thickness ranging from 50 nm to 110 nm.

13. (Cancelled)

14. (Currently Amended) The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer, a silicon nitride layer and a silicon oxynitride layer sequentially stacked, the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, the silicon nitride layer has a thickness ranging from 40 nm to 80 nm, and the silicon oxynitride layer has a thickness ranging from 10 nm to 60 nm.

15-17 (Cancelled)

18. (Currently Amended) The solar cell according to claim 1, wherein the semiconductor substrate is an N-type monocrystalline silicon substrate, the doped conductive layer is an N-type doped polycrystalline silicon layer, an N-type doped microcrystalline silicon layer or an N-type doped amorphous silicon layer, and the doped conductive layer has a thickness ranging from 60 nm to 200 nm.

19 (Cancelled)

20. (Original) A photovoltaic module, comprising a plurality of solar cell strings, wherein each of the plurality of solar cell strings comprises solar cells, and at least one of the solar cells comprises:

a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure has a non-pyramid-shaped microstructure and includes two or more first substructures at least partially stacked on one another, a top surface of the first substructure is a polygonal plane, and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ; and wherein a front surface of the semiconductor substrate has a second texture structure, the second texture structure includes a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ ;

a first passivation layer located on the second texture structure of the front surface of

the semiconductor substrate;

a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;

a doped conductive layer located on a surface of the tunnel oxide layer; and

a second passivation layer located on a surface of the doped conductive layer.

21. (New) The photovoltaic module according to claim 20, wherein for the two or more first substructures at least partially stacked on one another, in the direction away from the rear surface and perpendicular to the rear surface, a distance between the top surface of the outermost first substructure and the top surface of the adjacent first substructure is equal to or less than  $2\mu\text{m}$ .

22. (New) The photovoltaic module according to claim 20, wherein a shape of the polygonal plane includes at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square or a substantially trapezoid.

23. (New) The photovoltaic module according to claim 20, wherein a thickness of the tunnel oxide layer on the top surface of the outermost first substructure is less than a thickness of the tunnel oxide layer on a side surface of the outermost first substructure.

24. (New) The photovoltaic module according to claim 20, wherein the first texture structure further includes two or more adjacent second substructures that do not stacked on one another, and a one-dimensional size of a top surface of the second substructure away from the rear surface is less than or equal to  $45\mu\text{m}$ .

25. (New) The photovoltaic module according to claim 24, wherein the top surface of the second substructure is a polygonal plane.

26. (New) The photovoltaic module according to claim 20, wherein the tunnel oxide layer includes at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer, and the tunnel oxide layer has a thickness ranging from 0.8 nm to 2 nm.

27. (New) The photovoltaic module according to claim 20, wherein the second passivation layer includes at least one of a silicon nitride layer, a silicon oxide layer or a silicon oxynitride layer, and the second passivation layer has a thickness ranging from 70 nm to 120 nm.

**REMARKS**

Claims 1-7, 9, 11-12, 14, 18 and 20 are preliminary amended herein to be consistent with the allowed claims in the counterpart Japanese App. No. 2022-084397 for the purposes of PPH request being filed concurrently herewith. In addition, multiple dependency recited in claim 13 is expanded and now added as new claims 21-27. As a result, claims 8, 10, 13, 15-17 and 19 are canceled without prejudice or disclaimer. Applicant respectfully submits that no new matter is added. Examination on the merits is requested.

The Commissioner is hereby authorized to charge any fee required in connection with this filing, and any additional fees which may be required, or credit any overpayment to Deposit Account No. 19-2380.

Respectfully submitted,

/Sumiyo Onda, Reg. No. 62,166/  
Sumiyo Onda  
Registration No. 62,166

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TEL: (202) 585-8000

| <b>REQUEST FOR PARTICIPATION IN THE GLOBAL/IP5<br/>PATENT PROSECUTION HIGHWAY (PPH) PILOT PROGRAM IN THE USPTO</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                   |                       |                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-----------------------|-------------------|
| Application No.:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 17/964,190                                                        | First Named Inventor: | Kun YU            |
| Filing Date:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | October 12, 2022                                                  | Attorney Docket No.:  | 084546-000044USD1 |
| Title of Invention:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                       |                   |
| <b>THIS REQUEST FOR PARTICIPATION IN THE PPH PILOT PROGRAM ALONG WITH THE REQUIRED DOCUMENTS MUST BE SUBMITTED VIA THE USPTO PATENT ELECTRONIC FILING SYSTEM (EFS-WEB OR PATENT CENTER). INFORMATION REGARDING THE PATENT ELECTRONIC FILING SYSTEM IS AVAILABLE AT <a href="https://www.uspto.gov/efwc">https://www.uspto.gov/efwc</a></b>                                                                                                                                                                                                                                                        |                                                                   |                       |                   |
| <b>APPLICANT HEREBY REQUESTS PARTICIPATION IN THE PATENT PROSECUTION HIGHWAY (PPH) PILOT PROGRAM AND PETITIONS TO MAKE THE ABOVE-IDENTIFIED APPLICATION SPECIAL UNDER THE PPH PILOT PROGRAM.</b>                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                       |                   |
| <i>For national stage applications under 35 U.S.C. 371 only: This is an express request to begin national stage processing under 35 U.S.C. 371(f). Note: National stage processing will not commence prior to 30 months from the priority date absent an express request to begin national stage processing under 35 U.S.C. 371(f) and fulfillment of the requirements under 35 U.S.C. 371(c)(1), (2), and (4) for payment of the basic national fee, copy of the International Application and English translation thereof (if required), and the oath or declaration of the inventor(s).</i>    |                                                                   |                       |                   |
| <b>Office of earlier examination (OEE):</b> Japan (Japan Patent Office)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                   |                       |                   |
| <b>OEE application number:</b> 2022-084397                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                   |                       |                   |
| <b>Both the OEE application and the above-identified U.S. application have the following earliest date (filing or priority date):</b> August 4, 2021                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                   |                       |                   |
| <b>Type of OEE work product relied upon:</b> Decision to grant a patent                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                   |                       |                   |
| <b>Mailing date of OEE work product:</b> October 11, 2022                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                   |                       |                   |
| <b>Supporting Documents</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   |                       |                   |
| <b>1. OEE Work Product and Translation</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                   |                       |                   |
| A copy of the OEE work product and translation if not already in English:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                   |                       |                   |
| <input checked="" type="checkbox"/> Attached <input type="checkbox"/> Previously Submitted <input type="checkbox"/> Not required because the decision to grant a patent was the first office action                                                                                                                                                                                                                                                                                                                                                                                               |                                                                   |                       |                   |
| <input type="checkbox"/> Applicant requests the USPTO to attempt to obtain the OEE work product from the Dossier Access System or PATENTSCOPE                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                   |                       |                   |
| <small>NOTE: If the applicant requests the USPTO to obtain the OEE work product electronically and such attempt is unsuccessful, the applicant will be required to supply the document. Accordingly, to avoid dismissal of the initial PPH request and potential denial of participation in the PPH program, the applicant should verify that the OEE work product is actually available via the Dossier Access System or PATENTSCOPE before requesting retrieval. If the applicant is unable to verify availability, then the applicant should submit the document with the PPH request.</small> |                                                                   |                       |                   |
| <b>2. References Cited in OEE Work Product</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                   |                       |                   |
| An information disclosure statement (IDS) listing the references cited in the OEE work product and document copies (except U.S. patents and U.S. published patent applications):                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                       |                   |
| <input type="checkbox"/> Attached <input checked="" type="checkbox"/> Previously Submitted <input type="checkbox"/> Not required because no references were cited in the OEE work product                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                   |                       |                   |

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**REQUEST FOR PARTICIPATION IN THE GLOBAL/IP5 PPH PILOT PROGRAM IN THE USPTO**  
(continued)

|                  |            |                       |        |
|------------------|------------|-----------------------|--------|
| Application No.: | 17/964,190 | First Named Inventor: | Kun YU |
|------------------|------------|-----------------------|--------|

**3. Claims Correspondence Certification Statement**

All of the claims in this application sufficiently correspond to the patentable/allowable claims in the OEE application.

**4. Claims Correspondence Table**

| Claims in U.S. Application | Patentable/Allowable Claims in OEE Application | Explanation Regarding the Correspondence                                      |
|----------------------------|------------------------------------------------|-------------------------------------------------------------------------------|
| 1                          | 1                                              | Claim 1 sufficiently corresponds to claim 1 in OEE application                |
| 2                          | 2                                              | Claim 2 sufficiently corresponds to claim 2 in OEE application                |
| 3                          | 3                                              | Claim 3 sufficiently corresponds to claim 3 in OEE application                |
| 4                          | 4                                              | Claim 4 sufficiently corresponds to claim 4 in OEE application                |
| 5                          | 5                                              | Claim 5 sufficiently corresponds to claim 5 in OEE application                |
| 6                          | 6                                              | Claim 6 sufficiently corresponds to claim 6 in OEE application                |
| 7                          | 7                                              | Claim 7 sufficiently corresponds to claim 7 in OEE application                |
| 9                          | 8                                              | Claim 9 sufficiently corresponds to claim 8 in OEE application                |
| 11                         | 9                                              | Claim 11 sufficiently corresponds to claim 9 in OEE application               |
| 12                         | 10                                             | Claim 12 sufficiently corresponds to claim 10 in OEE application              |
| 14                         | 11                                             | Claim 14 sufficiently corresponds to claim 11 in OEE application              |
| 18                         | 12                                             | Claim 18 sufficiently corresponds to claim 12 in OEE application              |
| 20                         | 1, 13                                          | Claim 20 sufficiently corresponds to claims 1 and 13 in OEE application       |
| 21                         | 1, 2, 13                                       | Claim 21 sufficiently corresponds to claims 1, 2 and 13 in OEE application    |
| 22                         | 1, 3, 13                                       | Claim 22 sufficiently corresponds to claims 1, 3 and 13 in OEE application    |
| 23                         | 1, 4, 13                                       | Claim 23 sufficiently corresponds to claims 1, 4 and 13 in OEE application    |
| 24                         | 1, 5, 13                                       | Claim 24 sufficiently corresponds to claims 1, 5 and 13 in OEE application    |
| 25                         | 1, 5, 6, 13                                    | Claim 25 sufficiently corresponds to claims 1, 5, 6 and 13 in OEE application |
| 26                         | 1, 7, 13                                       | Claim 26 sufficiently corresponds to claims 1, 7 and 13 in OEE application    |
| 27                         | 1, 8, 13                                       | Claim 27 sufficiently corresponds to claims 1, 8 and 13 in OEE application    |
|                            |                                                |                                                                               |
|                            |                                                |                                                                               |
|                            |                                                |                                                                               |
|                            |                                                |                                                                               |

|                      |                                |                     |                  |
|----------------------|--------------------------------|---------------------|------------------|
| Signature            | /Sumiyo Onda, Reg. No. 62,166/ | Date                | October 26, 2022 |
| Name (print or type) | Sumiyo Onda                    | Registration Number | 62,166           |

## Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. The United States Patent and Trademark Office (USPTO) collects the information in this record under authority of 35 U.S.C. 2. The USPTO's system of records is used to manage all applicant and owner information including name, citizenship, residence, post office address and other information with respect to inventors and their legal representatives pertaining to the applicant's/owner's activities in connection with the invention for which a patent is sought or has been granted. The applicable Privacy Act System of Records Notice for this information is COMMERCE/PAT-TM-7 Patent Application Files, available in the Federal Register at 78 FR 19243 (March 29, 2013) (<https://www.govinfo.gov/content/pkg/FR-2013-03-29/pdf/2013-07341.pdf>).

Routine uses of this information may include disclosure to the following: to law enforcement and investigation in the event that the system of records indicates a violation or potential violation of law; to a Federal, state, local, or international agency, in response to its request; to an agency, organization, or individual for the purpose of performing audit or oversight operations as authorized by law; to non-federal personnel under contract to the agency; to a court for adjudication and litigation; to the Department of Justice for Freedom of Information Act (FOIA) assistance; to Members of Congress submitting a request involving an individual to whom the record pertains, when the individual has requested the Member's assistance with respect to the subject matter of the record; to the Office of Personnel Management (OPM) for personnel research purposes; to National Archives and Records Administration for inspection of records; and to the Office of Management and Budget (OMB) for legislative coordination and clearance. Failure to provide any part of the requested information may result in an inability to process requests for access and information.

| <b>PATENT APPLICATION FEE DETERMINATION RECORD</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                               |                                  |            |                                    |                 | Application or Docket Number<br>17/964,190 |                    |                         |                 |                         |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|------------|------------------------------------|-----------------|--------------------------------------------|--------------------|-------------------------|-----------------|-------------------------|--|
| Substitute for Form PTO-875                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    |                         |                 |                         |  |
| <b>APPLICATION AS FILED - PART I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    |                         |                 |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                               | (Column 1)                       | (Column 2) |                                    | SMALL ENTITY    |                                            | OR                 | OTHER THAN SMALL ENTITY |                 |                         |  |
| FOR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               | NUMBER FILED                     |            | NUMBER EXTRA                       | RATE(\$)        | FEE(\$)                                    |                    | RATE(\$)                | FEE(\$)         |                         |  |
| BASIC FEE<br>(37 CFR 1.16(a), (b), or (c))                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                               | N/A                              |            | N/A                                | N/A             |                                            |                    | N/A                     | 320             |                         |  |
| SEARCH FEE<br>(37 CFR 1.16(k), (l), or (m))                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                               | N/A                              |            | N/A                                | N/A             |                                            |                    | N/A                     | 700             |                         |  |
| EXAMINATION FEE<br>(37 CFR 1.16(o), (p), or (q))                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                               | N/A                              |            | N/A                                | N/A             |                                            |                    | N/A                     | 800             |                         |  |
| TOTAL CLAIMS<br>(37 CFR 1.16(i))                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 20                                                                                                                                                                                                                            | minus 20 =                       |            | 0                                  |                 |                                            | OR                 | x                       | = 0             |                         |  |
| INDEPENDENT CLAIMS<br>(37 CFR 1.16(h))                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2                                                                                                                                                                                                                             | minus 3 =                        |            |                                    |                 |                                            |                    | x                       | = 0             |                         |  |
| APPLICATION SIZE FEE<br>(37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). |                                  |            |                                    |                 |                                            |                    |                         | 0               |                         |  |
| MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    |                         | 0               |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                               |                                  |            |                                    | TOTAL           |                                            |                    | TOTAL                   | 1820            |                         |  |
| * If the difference in column 1 is less than zero, enter "0" in column 2.                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    |                         |                 |                         |  |
| <b>APPLICATION AS AMENDED - PART II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    |                         |                 |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                               | (Column 1)                       | (Column 2) |                                    | (Column 3)      |                                            | SMALL ENTITY       |                         | OR              | OTHER THAN SMALL ENTITY |  |
| AMENDMENT A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                               | CLAIMS REMAINING AFTER AMENDMENT |            | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA   | RATE(\$)                                   | ADDITIONAL FEE(\$) |                         | RATE(\$)        | ADDITIONAL FEE(\$)      |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Total<br>(37 CFR 1.16(i))                                                                                                                                                                                                     | *                                | Minus      | **                                 | =               | x                                          | =                  | OR                      | x               | =                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Independent<br>(37 CFR 1.16(h))                                                                                                                                                                                               | *                                | Minus      | ***                                | =               | x                                          | =                  | OR                      | x               | =                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                         |                                  |            |                                    |                 |                                            |                    | OR                      |                 |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    | OR                      |                 |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                               |                                  |            |                                    | TOTAL ADD'L FEE |                                            |                    | OR                      | TOTAL ADD'L FEE |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    |                         |                 |                         |  |
| AMENDMENT B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                               | CLAIMS REMAINING AFTER AMENDMENT |            | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA   | RATE(\$)                                   | ADDITIONAL FEE(\$) |                         | RATE(\$)        | ADDITIONAL FEE(\$)      |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Total<br>(37 CFR 1.16(i))                                                                                                                                                                                                     | *                                | Minus      | **                                 | =               | x                                          | =                  | OR                      | x               | =                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Independent<br>(37 CFR 1.16(h))                                                                                                                                                                                               | *                                | Minus      | ***                                | =               | x                                          | =                  | OR                      | x               | =                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                         |                                  |            |                                    |                 |                                            |                    | OR                      |                 |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    | OR                      |                 |                         |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                               |                                  |            |                                    | TOTAL ADD'L FEE |                                            |                    | OR                      | TOTAL ADD'L FEE |                         |  |
| <p style="font-size: x-small;">* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.</p> <p style="font-size: x-small;">** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".</p> <p style="font-size: x-small;">*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".</p> <p style="font-size: x-small;">The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.</p> |                                                                                                                                                                                                                               |                                  |            |                                    |                 |                                            |                    |                         |                 |                         |  |





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| APPLICATION<br>NUMBER | FILING or<br>371(c) DATE | GRP ART<br>UNIT | FIL FEE REC'D | ATTY. DOCKET NO   | TOT CLAIMS | IND CLAIMS |
|-----------------------|--------------------------|-----------------|---------------|-------------------|------------|------------|
| 17/964,190            | 10/12/2022               |                 | 1820          | 084546-000044USD1 | 20         | 2          |

CONFIRMATION NO. 7994

FILING RECEIPT



0000000050112869

22204

NIXON PEABODY, LLP  
799 Ninth Street, NW  
SUITE 500  
WASHINGTON, DC 20001

Date Mailed: 10/26/2022

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

**Please verify the accuracy of the data presented on this receipt.** If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

**Inventor(s)**

Kun YU, Haining, CHINA;  
Changming LIU, Haining, CHINA;  
Xinyu ZHANG, Haining, CHINA;

**Applicant(s)**

SHANHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD., Minhang  
District, CHINA;  
ZHEJIANG JINKO SOLAR CO., LTD., Haining, CHINA;

**Power of Attorney:** The patent practitioners associated with Customer Number 22204

**Domestic Priority data as claimed by applicant**

This application is a DIV of 17/459,689 08/27/2021

**Foreign Applications** (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.)

CHINA 202110895225.8 08/04/2021 Access Code Provided

**Permission to Access Application via Priority Document Exchange:** Yes

**Permission to Access Search Results:** Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

**Request to Retrieve** - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to Retrieve Electronic Priority Application(s)** (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

**If Required, Foreign Filing License Granted:** 10/24/2022

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 17/964,190**

**Projected Publication Date:** 02/09/2023

**Non-Publication Request:** No

**Early Publication Request:** No  
**Title**

SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE

**Preliminary Class**

**Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:** No

## **PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

## **LICENSE FOR FOREIGN FILING UNDER**

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### **Title 37, Code of Federal Regulations, 5.11 & 5.15**

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#### **NOT GRANTED**

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|                                                                                                                                 |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|--------------------------------------------|---------------|---------------------------|-----------|---------------------------------------|---------------------|---|
| <b>PATENT APPLICATION FEE DETERMINATION RECORD</b><br>Substitute for Form PTO-875                                               |                                                                                          |                                                                                                                                                                                                                               |                                    | Application or Docket Number<br>17/964,190 |               | Filing Date<br>10/12/2022 |           | <input type="checkbox"/> To be Mailed |                     |   |
| ENTITY: <input checked="" type="checkbox"/> LARGE <input type="checkbox"/> SMALL <input type="checkbox"/> MICRO                 |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
| <b>APPLICATION AS FILED - PART I</b>                                                                                            |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
|                                                                                                                                 |                                                                                          | (Column 1)                                                                                                                                                                                                                    | (Column 2)                         |                                            |               |                           |           |                                       |                     |   |
| FOR                                                                                                                             |                                                                                          | NUMBER FILED                                                                                                                                                                                                                  | NUMBER EXTRA                       |                                            | RATE (\$)     |                           | FEE (\$)  |                                       |                     |   |
| <input type="checkbox"/> BASIC FEE<br>(37 CFR 1.16(a), (b), or (c))                                                             |                                                                                          | N/A                                                                                                                                                                                                                           | N/A                                |                                            | N/A           |                           |           |                                       |                     |   |
| <input type="checkbox"/> SEARCH FEE<br>(37 CFR 1.16(k), (l), or (m))                                                            |                                                                                          | N/A                                                                                                                                                                                                                           | N/A                                |                                            | N/A           |                           |           |                                       |                     |   |
| <input type="checkbox"/> EXAMINATION FEE<br>(37 CFR 1.16(o), (p), or (q))                                                       |                                                                                          | N/A                                                                                                                                                                                                                           | N/A                                |                                            | N/A           |                           |           |                                       |                     |   |
| TOTAL CLAIMS<br>(37 CFR 1.16(j))                                                                                                |                                                                                          | minus 20 =                                                                                                                                                                                                                    | *                                  |                                            | x \$100 =     |                           |           |                                       |                     |   |
| INDEPENDENT CLAIMS<br>(37 CFR 1.16(h))                                                                                          |                                                                                          | minus 3 =                                                                                                                                                                                                                     | *                                  |                                            | x \$480 =     |                           |           |                                       |                     |   |
| <input type="checkbox"/> APPLICATION SIZE FEE (37 CFR 1.16(s))                                                                  |                                                                                          | If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). |                                    |                                            |               |                           |           |                                       |                     |   |
| <input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))                                                      |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
| * If the difference in column 1 is less than zero, enter "0" in column 2.                                                       |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            | TOTAL         |                           |           |                                       |                     |   |
| <b>APPLICATION AS AMENDED - PART II</b>                                                                                         |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
|                                                                                                                                 |                                                                                          | (Column 1)                                                                                                                                                                                                                    | (Column 2)                         |                                            | (Column 3)    |                           |           |                                       |                     |   |
| AMENDMENT                                                                                                                       | 10/26/2022                                                                               | CLAIMS REMAINING AFTER AMENDMENT                                                                                                                                                                                              | HIGHEST NUMBER PREVIOUSLY PAID FOR |                                            | PRESENT EXTRA |                           | RATE (\$) |                                       | ADDITIONAL FEE (\$) |   |
|                                                                                                                                 | Total<br>(37 CFR 1.16(i))                                                                | * 20                                                                                                                                                                                                                          | Minus                              | ** 20                                      | = 0           |                           | x \$100 = |                                       | 0                   |   |
|                                                                                                                                 | Independent<br>(37 CFR 1.16(h))                                                          | * 2                                                                                                                                                                                                                           | Minus                              | *** 3                                      | = 0           |                           | x \$480 = |                                       | 0                   |   |
|                                                                                                                                 | <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                           |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
|                                                                                                                                 | <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
|                                                                                                                                 |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           | TOTAL ADD'L FEE                       |                     | 0 |
| AMENDMENT                                                                                                                       |                                                                                          | (Column 1)                                                                                                                                                                                                                    | (Column 2)                         |                                            | (Column 3)    |                           |           |                                       |                     |   |
|                                                                                                                                 |                                                                                          | CLAIMS REMAINING AFTER AMENDMENT                                                                                                                                                                                              | HIGHEST NUMBER PREVIOUSLY PAID FOR |                                            | PRESENT EXTRA |                           | RATE (\$) |                                       | ADDITIONAL FEE (\$) |   |
|                                                                                                                                 | Total<br>(37 CFR 1.16(i))                                                                | *                                                                                                                                                                                                                             | Minus                              | **                                         | =             |                           | x \$0 =   |                                       |                     |   |
|                                                                                                                                 | Independent<br>(37 CFR 1.16(h))                                                          | *                                                                                                                                                                                                                             | Minus                              | ***                                        | =             |                           | x \$0 =   |                                       |                     |   |
|                                                                                                                                 | <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                           |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
| <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                        |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
|                                                                                                                                 |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           | TOTAL ADD'L FEE                       |                     |   |
| * If the entry in column 1 is less than the entry in column 2, write "0" in column 3.                                           |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           | LIE                                   |                     |   |
| ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".                                       |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           | /ANNIE C SINGLETON/                   |                     |   |
| *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".                                        |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |
| The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1. |                                                                                          |                                                                                                                                                                                                                               |                                    |                                            |               |                           |           |                                       |                     |   |

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

|                                      |   |                            |
|--------------------------------------|---|----------------------------|
| In re Patent Application             | ) |                            |
| (1.) Shanghai Jinko Green Energy     | ) | Art Unit: Not Yet Assigned |
| Enterprise Management Co., Ltd.      | ) |                            |
| (2.) Zhejiang Jinko Solar Co., Ltd.  | ) | Examiner: Not Yet Assigned |
| First Name Inventor: Kun YU et al.   | ) |                            |
| Based on Application No.: 17/459,689 | ) |                            |
| Filed: August 27, 2021               | ) |                            |
| For: SOLAR CELL, MANUFACTURING       | ) |                            |
| METHOD THEREOF, AND                  | ) |                            |
| PHOTOVOLTAIC MODULE                  | ) |                            |
|                                      | ) |                            |

**INFORMATION DISCLOSURE STATEMENT**

**Mail Stop New Application – Via EFS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Sir:

In accordance with the duty of disclosure as set forth in 37 C.F.R. §1.56, Applicants hereby submit the following information in conformance with 37 C.F.R. §§ 1.97 and 1.98. In accordance with the policies of the U.S. Patent and Trademark Office, only copies of newly cited foreign patents and non-patent literature are being submitted.

Applicant submits that the references listed on the attached Form PTO-1449 were previously cited in a parent U.S. Application No. 17/459,689 filed August 27, 2021, from which priority is claimed under 35 U.S.C. §120.

It is requested that the accompanying PTO-1449 be considered and made of record in the above-identified application. It is respectfully requested that an Examiner initialed copy of this form be returned to the undersigned.

The present Information Disclosure Statement is filed within three months of filing, or before the mailing of a first Office action on the merits, whichever is later; therefore, no fee is believed to be necessary at this time.

However, if a fee becomes necessary, the Commissioner is hereby authorized by this paper to charge any additional fees, except the issue fee, during the entire pendency of this application including fees due under 37 C.F.R. §§ 1.16 and 1.17 which may be required, including any required extension of time fees, or credit any overpayment to Deposit Account No. 19-2380.

Respectfully submitted,

By: /Jeffrey L. Costellia, Reg.#35483/  
Jeffrey L. Costellia  
Registration No. 35,483

**NIXON PEABODY LLP**  
Customer No. 22204  
799 9<sup>th</sup> Street NW., Suite 500  
Washington, D.C. 20001-4501  
TEL: (202) 585-8000

|                                                                                                                                       |   |    |   |                          |                   |
|---------------------------------------------------------------------------------------------------------------------------------------|---|----|---|--------------------------|-------------------|
| Substitute for form 1449A/PTO<br><b>INFORMATION DISCLOSURE<br/>STATEMENT BY APPLICANT</b><br><i>(use as many sheets as necessary)</i> |   |    |   | <b>Complete if Known</b> |                   |
|                                                                                                                                       |   |    |   | Application Number       | Not Yet Assigned  |
|                                                                                                                                       |   |    |   | Filing Date              | October 12, 2022  |
|                                                                                                                                       |   |    |   | First Named Inventor     | Kun YU et al.     |
|                                                                                                                                       |   |    |   | Art Unit                 | Not Yet Assigned  |
|                                                                                                                                       |   |    |   | Examiner Name            | Not Yet Assigned  |
| Sheet                                                                                                                                 | 1 | of | 2 | Attorney Docket Number   | 084546-000044USD1 |

| U.S. PATENT DOCUMENTS |                       |                                            |                                |                                                    |                                                                                 |
|-----------------------|-----------------------|--------------------------------------------|--------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------|
| Examiner Initials*    | Cite No. <sup>1</sup> | U.S. Patent Document                       | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines, Where<br>Relevant Passages or Relevant<br>Figures Appear |
|                       |                       | Number - Kind Code <sup>2</sup> (if known) |                                |                                                    |                                                                                 |
|                       |                       | US-2018/0182905 A1                         | 06-28-2018                     | NAM et al.                                         |                                                                                 |
|                       |                       | US-2018/0315866 A1                         | 11-01-2018                     | CHEONG et al.                                      |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |
|                       |                       | US-                                        |                                |                                                    |                                                                                 |

| FOREIGN PATENT DOCUMENTS |                       |                                                                                    |                                |                                                    |                                                                                    |                |
|--------------------------|-----------------------|------------------------------------------------------------------------------------|--------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------|----------------|
| Examiner Initials*       | Cite No. <sup>1</sup> | Foreign Patent Document                                                            | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines,<br>Where Relevant<br>Passages or Relevant<br>Figures Appear | T <sup>6</sup> |
|                          |                       | Country Code <sup>3</sup> Number <sup>4</sup> Kind Code <sup>5</sup><br>(if known) |                                |                                                    |                                                                                    |                |
|                          |                       | CN-111628049                                                                       | 09-04-2020                     |                                                    |                                                                                    | Abstract       |
|                          |                       | CN-212750903                                                                       | 03-19-2021                     |                                                    |                                                                                    | Abstract       |
|                          |                       | EP-2149915                                                                         | 02-03-2010                     |                                                    |                                                                                    | Eng.           |
|                          |                       | EP-2645421                                                                         | 10-02-2013                     |                                                    |                                                                                    | Eng.           |
|                          |                       | WO-2015/122257                                                                     | 08-20-2015                     |                                                    |                                                                                    | Abstract       |
|                          |                       | CN-112599615                                                                       | 04-02-2021                     |                                                    |                                                                                    | Abstract       |
|                          |                       | JP-2012-216788                                                                     | 11-08-2012                     |                                                    |                                                                                    | Abstract       |
|                          |                       | WO-2016/129481                                                                     | 08-18-2016                     |                                                    |                                                                                    | Abstract       |
|                          |                       |                                                                                    |                                |                                                    |                                                                                    |                |
|                          |                       |                                                                                    |                                |                                                    |                                                                                    |                |

| OTHER PRIOR ART - NON PATENT LITERATURE DOCUMENTS |                       |                                                                                                                                                                                                                                                                 |                |
|---------------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Examiner Initials*                                | Cite No. <sup>1</sup> | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published. | T <sup>2</sup> |
|                                                   |                       | Extended European Search Report for EP App. No. 21194044.0, mailed Dec 2, 2021, 7 pages.                                                                                                                                                                        | Eng.           |
|                                                   |                       | Japan Office Action (Application No. 2021-137285) mailed January 11, 2022 (17 pages).                                                                                                                                                                           | Eng.           |
|                                                   |                       |                                                                                                                                                                                                                                                                 |                |

|                    |  |                 |  |
|--------------------|--|-----------------|--|
| Examiner Signature |  | Date Considered |  |
|--------------------|--|-----------------|--|

\*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

<sup>1</sup> Applicant's unique citation designation number (optional). <sup>2</sup> See Kinds Codes of USPTO Patent Documents at [www.uspto.gov](http://www.uspto.gov) or MPEP 901.04. <sup>3</sup> Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). <sup>4</sup> For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. <sup>5</sup> Kind of document by the

|                                                                                                                                           |                  |    |   |                          |                   |
|-------------------------------------------------------------------------------------------------------------------------------------------|------------------|----|---|--------------------------|-------------------|
| Substitute for form 1449A/PTO<br><br><b>INFORMATION DISCLOSURE<br/>STATEMENT BY APPLICANT</b><br><i>(use as many sheets as necessary)</i> |                  |    |   | <b>Complete if Known</b> |                   |
|                                                                                                                                           |                  |    |   | Application Number       | Not Yet Assigned  |
|                                                                                                                                           |                  |    |   | Filing Date              | October 12, 2022  |
|                                                                                                                                           |                  |    |   | First Named Inventor     | Kun YU et al.     |
|                                                                                                                                           |                  |    |   | Art Unit                 | Not Yet Assigned  |
| Examiner Name                                                                                                                             | Not Yet Assigned |    |   |                          |                   |
| Sheet                                                                                                                                     | 2                | of | 2 | Attorney Docket Number   | 084546-000044USD1 |

| U.S. PATENT DOCUMENTS |                          |                                            |                                |                                                    |                                                                                 |
|-----------------------|--------------------------|--------------------------------------------|--------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------|
| Examiner<br>Initials* | Cite<br>No. <sup>1</sup> | U.S. Patent Document                       | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines, Where<br>Relevant Passages or Relevant<br>Figures Appear |
|                       |                          | Number - Kind Code <sup>2</sup> (if known) |                                |                                                    |                                                                                 |
|                       |                          | US-2018/0018295                            | 01-18-2018                     | Chen et al.                                        |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |
|                       |                          | US-                                        |                                |                                                    |                                                                                 |

| FOREIGN PATENT DOCUMENTS |                          |                                                                                    |                                |                                                    |                                                                                    |                |
|--------------------------|--------------------------|------------------------------------------------------------------------------------|--------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------|----------------|
| Examiner<br>Initials*    | Cite<br>No. <sup>1</sup> | Foreign Patent Document                                                            | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines,<br>Where Relevant Passages<br>or Relevant Figures<br>Appear | T <sup>6</sup> |
|                          |                          | Country Code <sup>3</sup> Number <sup>4</sup><br>Kind Code <sup>5</sup> (if known) |                                |                                                    |                                                                                    |                |
|                          |                          | CN-110931596                                                                       | 03-27-2020                     |                                                    |                                                                                    | Abstract       |
|                          |                          | JP-6-61515                                                                         | 03-04-1994                     |                                                    |                                                                                    | Abstract       |
|                          |                          |                                                                                    |                                |                                                    |                                                                                    |                |
|                          |                          |                                                                                    |                                |                                                    |                                                                                    |                |
|                          |                          |                                                                                    |                                |                                                    |                                                                                    |                |

| OTHER PRIOR ART – NON PATENT LITERATURE DOCUMENTS |                          |                                                                                                                                                                                                                                                                 |                |
|---------------------------------------------------|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Examiner<br>Initials*                             | Cite<br>No. <sup>1</sup> | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published. | T <sup>2</sup> |
|                                                   |                          | Notification of Reasons for Refusal for Japanese App. No. 2022-084397, mailed August 2, 2022 (4 pages).                                                                                                                                                         | Machine Trans. |
|                                                   |                          | Australian Notice of Acceptance for Application No. 2021225144, mailed June 10, 2022 (6 pages).                                                                                                                                                                 | Eng.           |
|                                                   |                          |                                                                                                                                                                                                                                                                 |                |

|                       |  |                    |  |
|-----------------------|--|--------------------|--|
| Examiner<br>Signature |  | Date<br>Considered |  |
|-----------------------|--|--------------------|--|

\*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

<sup>1</sup> Applicant's unique citation designation number (optional). <sup>2</sup> See Kinds Codes of USPTO Patent Documents at [www.uspto.gov](http://www.uspto.gov) or MPEP 901.04. <sup>3</sup> Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). <sup>4</sup> For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. <sup>5</sup> Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. <sup>6</sup> Applicant is to place a check mark here if English language Translation is attached.

<sup>1</sup> Applicant's unique citation designation number (optional). <sup>2</sup> Applicant is to place a check mark here if English language Translation is attached.

| Electronic Patent Application Fee Transmittal |          |                                                                   |        |                      |
|-----------------------------------------------|----------|-------------------------------------------------------------------|--------|----------------------|
| Application Number:                           |          |                                                                   |        |                      |
| Filing Date:                                  |          |                                                                   |        |                      |
| Title of Invention:                           |          | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |        |                      |
| First Named Inventor/Applicant Name:          |          | Kun YU                                                            |        |                      |
| Filer:                                        |          | Jeffrey Costellia/Donald Sias                                     |        |                      |
| Attorney Docket Number:                       |          | 084546-000044USD1                                                 |        |                      |
| Filed as Large Entity                         |          |                                                                   |        |                      |
| Filing Fees for Utility under 35 USC 111(a)   |          |                                                                   |        |                      |
| Description                                   | Fee Code | Quantity                                                          | Amount | Sub-Total in USD(\$) |
| <b>Basic Filing:</b>                          |          |                                                                   |        |                      |
| UTILITY APPLICATION FILING                    | 1011     | 1                                                                 | 320    | 320                  |
| UTILITY SEARCH FEE                            | 1111     | 1                                                                 | 700    | 700                  |
| UTILITY EXAMINATION FEE                       | 1311     | 1                                                                 | 800    | 800                  |
| <b>Pages:</b>                                 |          |                                                                   |        |                      |
| <b>Claims:</b>                                |          |                                                                   |        |                      |
| <b>Miscellaneous-Filing:</b>                  |          |                                                                   |        |                      |
| <b>Petition:</b>                              |          |                                                                   |        |                      |
| <b>Patent-Appeals-and-Interference:</b>       |          |                                                                   |        |                      |

| Description                              | Fee Code | Quantity | Amount | Sub-Total in USD(\$) |
|------------------------------------------|----------|----------|--------|----------------------|
| <b>Post-Allowance-and-Post-Issuance:</b> |          |          |        |                      |
| <b>Extension-of-Time:</b>                |          |          |        |                      |
| <b>Miscellaneous:</b>                    |          |          |        |                      |
| <b>Total in USD (\$)</b>                 |          |          |        | <b>1820</b>          |

| Electronic Acknowledgement Receipt          |                                                                   |
|---------------------------------------------|-------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 46799482                                                          |
| <b>Application Number:</b>                  | 17964190                                                          |
| <b>International Application Number:</b>    |                                                                   |
| <b>Confirmation Number:</b>                 | 7994                                                              |
| <b>Title of Invention:</b>                  | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |
| <b>First Named Inventor/Applicant Name:</b> | Kun YU                                                            |
| <b>Customer Number:</b>                     | 22204                                                             |
| <b>Filer:</b>                               | Jeffrey Costellia/Donald Sias                                     |
| <b>Filer Authorized By:</b>                 | Jeffrey Costellia                                                 |
| <b>Attorney Docket Number:</b>              | 084546-000044USD1                                                 |
| <b>Receipt Date:</b>                        | 12-OCT-2022                                                       |
| <b>Filing Date:</b>                         |                                                                   |
| <b>Time Stamp:</b>                          | 12:24:34                                                          |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)                                       |

### Payment information:

|                                                                                                                |                  |
|----------------------------------------------------------------------------------------------------------------|------------------|
| Submitted with Payment                                                                                         | yes              |
| Payment Type                                                                                                   | DA               |
| Payment was successfully received in RAM                                                                       | \$1820           |
| RAM confirmation Number                                                                                        | E20220BC25030017 |
| Deposit Account                                                                                                |                  |
| Authorized User                                                                                                |                  |
| The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: |                  |

| <b>File Listing:</b>                            |                                                            |                                                                       |                                                              |                  |                  |
|-------------------------------------------------|------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------|------------------|------------------|
| Document Number                                 | Document Description                                       | File Name                                                             | File Size(Bytes)/<br>Message Digest                          | Multi Part /.zip | Pages (if appl.) |
| 1                                               |                                                            | 084546_000044USD1_Specifica<br>tion_and_Drawings.pdf                  | 1015130<br><br>7990ed30bb102abea0f30df90048c33f0275<br>db90  | yes              | 46               |
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| 3                                               | Application Data Sheet                                     | 084546_000044USD1_Applicati<br>on_Data_Sheet.pdf                      | 429810<br><br>6eaf5e811f7b243e8f2876c47048aede931b<br>46a3   | no               | 9                |
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| 4                                               | Power of Attorney                                          | 084546_000044USD1_Power_o<br>f_Attorney_Statement_Record<br>ation.pdf | 8737277<br><br>a81e95160915bfdf33ac0fc49de78ebde9b2<br>d10f4 | no               | 10               |
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| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                       |                                           |                                          |    |   |
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| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                       |                                           |                                          |    |   |
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| <p><b>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</b></p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p> |                                                       |                                           |                                          |    |   |

# **SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE**

## **CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] The present application is a divisional of U.S. Application No. 17/459,689, filed on  
5 August 27, 2021, which claims priority to Chinese Patent Application No. 202110895225.8,  
filed on August 04, 2021, the contents of both of which are incorporated herein by reference in  
their entireties.

## **TECHNICAL FIELD**

[0001] The present disclosure relates to the field of photovoltaic cell technologies, and in  
10 particular, to a solar cell, a manufacturing method thereof, and a photovoltaic module.

## **BACKGROUND**

[0002] An N-type tunnel oxide passivated contact (TOPCon) solar cell relies on a "tunnel  
effect" to achieve passivated contact on a rear surface of the solar cell. When manufacturing the  
TOPCon solar cell, borosilicate glass is formed by boron diffusion on a surface of a silicon  
15 wafer (or a substrate), which is more difficult to be removed compared with phosphorosilicate  
glass of a conventional PERC solar cell. Generally, borosilicate glass on a rear surface of an N-  
type solar cell is removed by an oxidizing mixed acid solution. After the surface is cleaned and  
dried, the rear surface is polished with the aid of a trough or chain acid additive. The polished  
rear surface of the silicon wafer has a flat structure, but the structure of the polished rear surface  
20 may directly affect the manufacturing of the tunnel oxide layer and the polycrystalline silicon  
layer, and then affect passivation performance and conversion efficiency of the solar cell.

## SUMMARY

**[0003]** In view of the above, the present disclosure provides a solar cell, a manufacturing method thereof, and a photovoltaic module, which, through matching between texture structures on substrate surfaces of the solar cell, can improve an open-circuit voltage of the solar cell, reduce contact resistance of a metal electrode, and improve conversion efficiency of the solar cell.

**[0004]** In a first aspect, the present disclosure provides a solar cell, including:

a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure includes two or more first substructures at least partially stacked on one another, and in a direction away from the rear surface and perpendicular to the rear surface, a distance between a top surface of an outermost first substructure and a top surface of an adjacent first substructure is less than or equal to 2  $\mu\text{m}$ , and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ;

a first passivation layer located on a front surface of the semiconductor substrate;

a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;

a doped conductive layer located on a surface of the tunnel oxide layer, a conductivity type of doping elements of the doped conductive layer being same as that of the semiconductor substrate; and

a second passivation layer located on a surface of the doped conductive layer.

**[0005]** In an implementation, the front surface of the semiconductor substrate has a second texture structure, the second texture structure includes a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ .

**[0006]** In an implementation, for the two or more first substructures at least partially stacked

on one another, in the direction away from the rear surface and perpendicular to the rear surface, the distance between the top surface of the outermost first substructure and the top surface of the adjacent first substructure ranges from 0.3  $\mu\text{m}$  to 1.2  $\mu\text{m}$ .

5     **[0007]**     In an implementation, an average one-dimensional size of the top surface of the outermost first substructure ranges from 10  $\mu\text{m}$  to 15  $\mu\text{m}$ .

**[0008]**     In an implementation, a thickness of the tunnel oxide layer on the top surface of the outermost first substructure is less than a thickness of the tunnel oxide layer on a side surface of the outermost first substructure.

10    **[0009]**     In an implementation, a thickness difference between the tunnel oxide layer on the top surface of the outermost first substructure and the tunnel oxide layer on a side surface of the outermost first substructure is less than or equal to 0.15 nm.

**[0010]**     In an implementation, the first texture structure further includes two or more adjacent second substructures that do not stacked on one another, and a one-dimensional size of a top surface of the second substructure away from the rear surface is less than or equal to  
15    45  $\mu\text{m}$ .

**[0011]**     In an implementation, the top surface of the first substructure and/or the top surface of the second substructure is a polygonal plane.

**[0012]**     In an implementation, a shape of the polygonal plane includes at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square or a substantially  
20    trapezoid.

**[0013]**     In an implementation, the tunnel oxide layer includes at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer, and the tunnel oxide layer has a thickness ranging from 0.8 nm to 2 nm.

**[0014]**     In an implementation, the second passivation layer includes at least one of a silicon  
25    nitride layer, a silicon oxide layer or a silicon oxynitride layer, and the second passivation layer has a thickness ranging from 70 nm to 120 nm.

**[0015]**     In an implementation, the first passivation layer includes at least one of a silicon oxide layer, a silicon nitride layer, an aluminum oxide layer or a silicon oxynitride layer.

**[0016]**     In an implementation, the semiconductor substrate is an N-type monocrystalline  
30    silicon substrate, the doped conductive layer is an N-type doped polycrystalline silicon layer,

an N-type doped microcrystalline silicon layer or an N-type doped amorphous silicon layer, and the doped conductive layer has a thickness ranging from 60 nm to 200 nm.

5     **[0017]**     In a second aspect, the present disclosure provides a photovoltaic module, including a plurality of solar cell strings, each of the plurality of solar cell strings including the solar cell described in the first aspect.

**[0018]**     In a third aspect, the present disclosure provides a method for manufacturing a solar cell, including:

10             texturing a semiconductor substrate, and forming a second texture structure on a front surface of the semiconductor substrate, wherein the second texture structure includes a pyramid-shaped microstructure;

              forming a doped layer with doping elements to the front surface of the textured semiconductor substrate;

15             polishing a rear surface of the semiconductor substrate with an alkali solution, such that a first texture structure is formed on the rear surface of the semiconductor substrate, wherein the first texture structure includes two or more first substructures at least partially stacked on one another, and in a direction away from the rear surface and perpendicular to the rear surface, a distance between a top surface of an outermost first substructure and a top surface of an adjacent first substructure is less than or equal to 2  $\mu\text{m}$ , and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ;

20             forming a tunnel oxide layer on the first texture structure of the rear surface of the semiconductor substrate;

              depositing a polycrystalline silicon layer on a surface of the tunnel oxide layer, and forming a doped conductive layer by doping the polycrystalline silicon layer, wherein the doped conductive layer and the semiconductor substrate have doping elements of a same conductivity type;

25             forming a first passivation layer on the front surface of the semiconductor substrate; and

              forming a second passivation layer on a surface of the doped conductive layer.

30     **[0019]**     In an implementation, the polishing a rear surface of the semiconductor substrate with an alkali solution includes: cleaning the rear surface of the semiconductor substrate with

the alkali solution having a mass fraction of 5% to 15% to remove porous silicon; dropping, by spraying, micro-liquid droplets of the alkali solution to the rear surface of the semiconductor substrate for roughening treatment, and then performing pre-cleaning with a hydrofluoric acid having a mass fraction of 5% to 10%; polishing the rear surface of the semiconductor substrate with a polishing liquid at a polishing temperature ranging from 70°C to 80°C for a polishing time less than 260 seconds, wherein the polishing liquid includes NaOH having a mass fraction of 1% to 15%, KOH having a mass fraction of 1% to 15% and an additive having a mass fraction of 0.51% to 2.5%; removing organic components in the polishing liquid by a mixture of potassium hydroxide having a mass fraction of 5% to 15% and hydrogen peroxide having a mass fraction of 15% to 40%; and washing and drying the polished semiconductor substrate.

**[0020]** In an implementation, the forming a tunnel oxide layer includes at least one of: (1) depositing the tunnel oxide layer on the first texture structure of the rear surface of the semiconductor substrate by a temperature change process and chemical vapor deposition; (2) during the deposition of the tunnel oxide layer, controlling a heating rate to range from 0.5°C/min to 3°C/min, a deposition temperature to range from 560°C to 620°C and a deposition time to range from 3 min to 10 min; (3) a deposition temperature of the tunnel oxide layer being lower than a deposition temperature of the polycrystalline silicon layer; (4) the tunnel oxide layer including at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer; and (5) the tunnel oxide layer having a thickness ranging from 0.8 nm to 2 nm.

## BRIEF DESCRIPTION OF DRAWINGS

**[0021]** In order to better illustrate the technical solutions in embodiments of the present disclosure or the prior art, the accompanying drawings used in the description of the embodiments or the prior art will be briefly introduced below. It is apparent that, the accompanying drawings in the following description are only some embodiments of the present disclosure, and other drawings can be obtained by those of ordinary skill in the art from the provided drawings without creative efforts.

**[0022]** FIG. 1 is a schematic structural diagram of a solar cell according to an embodiment

of the present disclosure.

**[0023]** FIG. 2 is an electron microscope picture of a second texture structure on a front surface of a semiconductor substrate of a solar cell according to an embodiment of the present disclosure.

5 **[0024]** FIG. 3 is an electron microscope picture of a first texture structure on a rear surface of the semiconductor substrate of the solar cell according to an embodiment of the present disclosure.

**[0025]** FIG. 4a is a schematic structural diagram of a first substructure in the first texture structure of the rear surface of the semiconductor substrate of the solar cell according to an  
10 embodiment of the present disclosure.

**[0026]** FIG. 4b is a schematic structural diagram of another first substructure in the first texture structure of the rear surface of the semiconductor substrate of the solar cell according to an embodiment of the present disclosure.

**[0027]** FIG. 5 is a schematic structural diagram of a substructure in the first texture structure  
15 of the rear surface of the semiconductor substrate of the solar cell according to an embodiment of the present disclosure.

**[0028]** FIG. 6 is a schematic structural diagram of a tunnel oxide layer on the first texture structure of the rear surface of the semiconductor substrate of the solar cell according to an embodiment of the present disclosure.

20 **[0029]** FIG. 7a is a schematic structural diagram of a photovoltaic module according to an embodiment of the present disclosure.

**[0030]** FIG. 7b is a top view of the photovoltaic module according to an embodiment of the present disclosure.

**[0031]** FIG. 8 is a schematic flowchart of a method for manufacturing a solar cell according  
25 to an embodiment of the present disclosure.

## DESCRIPTION OF EMBODIMENTS

**[0032]** In order to better understand the technical solutions of the present disclosure, the embodiments of the present disclosure are described in detail below with reference to the

accompanying drawings.

**[0033]** It shall be made clear that the embodiments described are merely some embodiments rather than all of the embodiments of the present disclosure. All other embodiments obtained by those of ordinary skill in the art without creative efforts based on the embodiments of the present disclosure shall fall within the protection scope of the present disclosure.

**[0034]** The terms used in the embodiments of the present disclosure are merely for the purpose of describing particular embodiments and are not intended to limit the present disclosure. As used in the embodiments of the present disclosure and the appended claims, the singular forms of “a/an”, “one”, and “the” are also intended to include plural forms, unless otherwise clearly specified by the context.

**[0035]** It shall be understood that the term "and/or" used herein describes only an association relationship between associated objects and indicates that three relationships may exist. For example, A and/or B may indicate the following three cases: only A exists, both A and B exist, and only B exists. In addition, the character "/" generally indicates an "or" relationship between the associated objects.

**[0036]** The TOPCon solar cell relies on a "tunnel effect" to passivate the rear surface. An existing TOPCon solar cell rear surface structure sequentially includes a semiconductor substrate, a tunnel oxide layer, a doped conductive layer and a passivation layer on the rear surface from the inside out. Borosilicate glass (BSG) can be formed by in boron diffusion for an N-type TOPCon solar cell, which is more difficult to be removed than phosphorosilicate glass (PSG). Generally, the borosilicate glass is removed by an oxidizing mixed acid solution. The rear surface is polished after the surface is cleaned and dried. Currently, a state of the rear surface of the semiconductor substrate after polishing has a certain effect on an ultra-thin tunnel oxide layer with a nanometer thickness, which easily leads to an increase in contact resistivity between the tunnel oxide layer and the semiconductor substrate, which in turn leads to the fluctuation of a fill factor of the solar cell, and finally affects the photoelectric conversion efficiency of the solar cell.

**[0037]** In a first aspect, the present disclosure provides a solar cell. As shown in FIG. 1, the solar cell includes: a semiconductor substrate 10, a first passivation layer 20 located on a front surface of the semiconductor substrate 10, a tunnel oxide layer 30 located on the first texture

structure of a rear surface of the semiconductor substrate 10, a doped conductive layer 40 located on a surface of the tunnel oxide layer 30, and a second passivation layer 50 located on a surface of the doped conductive layer 40. The rear surface of the semiconductor substrate 10 has a first texture structure 12, and the first texture structure 12 includes two or more first substructures that are at least partially stacked on one another. In a direction away from the rear surface and perpendicular to the rear surface, a distance between a top surface of the outermost first substructure and a top surface of the first substructure adjacent thereto is less than or equal to 2  $\mu\text{m}$ . A one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ , a front surface of the semiconductor substrate 10 has a second texture structure 11, and the second texture structure 11 may include a pyramid-shaped microstructure. The doped conductive layer and the semiconductor substrate have doping elements of a same conductivity type.

**[0038]** The front surface of the semiconductor substrate 10 may refer to a light receiving surface, that is, a surface receiving solar rays. The rear surface of the semiconductor substrate 10 refers to a surface opposite the front surface. In some embodiments, the solar cell formed is a single-sided solar cell. The front surface may refer to a light receiving surface, and the rear surface may refer to a backlight surface. In some embodiments, the solar cell formed is a double-sided solar cell. The front surface and the rear surface may both be light receiving surfaces.

**[0039]** As an optional technical solution of the present disclosure, the semiconductor substrate 10 is an N-type crystalline silicon substrate (or silicon wafer). A P-type doped layer may be formed on the front surface of the semiconductor substrate by one or more of the processes of high temperature diffusion, slurry doping, and ion implantation, so as to form a PN junction in the semiconductor substrate 10. In some embodiments, the semiconductor substrate 10 may be one of a monocrystalline silicon substrate, a polycrystalline silicon substrate, a microcrystalline silicon substrate and a silicon carbide substrate.

**[0040]** In some embodiments, the P-type doped layer is a boron-doped diffusion layer. The boron-doped diffusion layer is a P-type doped layer (i.e., P<sup>+</sup> layer) formed by using a boron source to diffuse boron atoms to a certain depth on the front surface through a diffusion process. For example, the boron source may be liquid boron tribromide.

**[0041]** In some embodiments, as shown in FIG. 2, the front surface of the semiconductor substrate 10 has a second texture structure 11, and the second texture structure 11 includes a pyramid-shaped microstructure 111. The pyramid-shaped microstructure 111 may have a structure of a tetrahedron, a substantially tetrahedron, a pentahedron, a substantially pentahedron, or the like. The pyramid-shaped microstructure 111 may be formed by texturing the semiconductor substrate. The texturing process may be chemical etching, laser etching, a mechanical process, plasma etching, or the like. The pyramid-shaped microstructure enables a metal paste to better fill the microstructure when the metal paste forms an electrode by screen printing, which obtains better electrode contact, can effectively reduce series resistance of the solar cell, and improves the fill factor.

**[0042]** In some embodiments, the pyramid-shaped microstructure 111 includes a top away from the front surface of the semiconductor substrate and a bottom close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance (or height) between the top and the bottom of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ . For example, the distance ranges from 2  $\mu\text{m}$  to 5  $\mu\text{m}$ . The distance may be 2  $\mu\text{m}$ , 2.5  $\mu\text{m}$ , 2.8  $\mu\text{m}$ , 3  $\mu\text{m}$ , 3.5  $\mu\text{m}$ , 3.8  $\mu\text{m}$ , 4  $\mu\text{m}$ , 4.2  $\mu\text{m}$ , 4.5  $\mu\text{m}$ , 4.8  $\mu\text{m}$ , 5  $\mu\text{m}$  or the like. When the distance range of the pyramid-shaped microstructure 111 is controlled within 5  $\mu\text{m}$ , for example, 2  $\mu\text{m}$  to 5  $\mu\text{m}$ , the pyramid-shaped microstructure 111 has the characteristics of low reflection, low recombination and easy filling, so that the photoelectric conversion efficiency of the solar cell can be improved.

**[0043]** It may be understood that a number of the pyramid-shaped microstructure formed on the front surface cannot be exhausted due to anisotropy of crystal orientation of silicon crystal on the front surface. The distance of the pyramid-shaped microstructure 111 referred to herein may be a distance between a convex highest point of the top and a concave lowest point of the pyramid-shaped microstructure 111 randomly selected in a specific region. For example, the distance of the pyramid-shaped microstructure 111 may be determined by measuring a surface shape of the semiconductor substrate by using an atomic force microscope (AFM). For example, a scanning range of 40  $\mu\text{m}$ ×40  $\mu\text{m}$  is selected from the front surface, the front surface of the semiconductor substrate is scanned within the selected range by using the atomic force microscope, a profile size of the pyramid-shaped microstructure on the front surface is

measured, and a height value  $h$  is calculated. The convex highest point  $h_a$  of the top of the pyramid-shaped microstructure is selected from the measured profile size (an AFM image), the lowest point of the bottom corresponding to the top is  $h_b$ , and  $h=h_a-h_b$  is obtained. In other implementations, heights of a plurality of pyramid-shaped microstructures in the second texture structure are randomly collected, and an average value is calculated. The average value is defined as the height of the pyramid-shaped microstructure. For example, 4 pyramid-shaped microstructures 111 are randomly selected, with heights of  $h_1$ ,  $h_2$ ,  $h_3$  and  $h_4$  respectively, and then a height value of the pyramid-shaped microstructure 111 is  $(h_1+h_2+h_3+h_4)/4$ . That is, an average distance of a plurality of pyramid-shaped microstructures 111 can be regarded as a distance of the pyramid-shaped microstructure on the front surface, which is configured to represent a texture feature of the front surface.

**[0044]** As an optional technical solution of the present disclosure, the first passivation layer 20 has a stacking structure of at least one or more of a silicon oxide layer, a silicon nitride layer, an aluminum oxide layer and a silicon oxynitride layer.

**[0045]** In some embodiments, the first passivation layer 20 has a thickness ranging from 10 nm to 120 nm, which may be 10 nm, 20 nm, 30 nm, 40 nm, 50 nm, 60 nm, 70 nm, 80 nm, 90 nm, 100 nm, 120 nm or the like, and may also be other values in the range, which is not limited herein.

**[0046]** In an embodiment, the first passivation layer 20 has a stacked passivation structure of an aluminum oxide layer and a silicon nitride layer. The aluminum oxide layer is arranged on the front surface of the semiconductor substrate 10. The silicon nitride layer is arranged on a surface of the aluminum oxide layer. For example, the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, and the aluminum oxide layer has a refractive index ranging from 1.5 to 1.8. The silicon nitride layer has a thickness ranging from 50 nm to 110 nm, and the silicon nitride layer has a refractive index ranging from 1.65 to 2.25. The first passivation layer 20 has an overall refractive index ranging from 1.9 to 2.0. The aluminum oxide layer or silicon nitride layer may include a plurality of sublayers. For example, the silicon nitride layer is composed of 2 to 5 silicon nitride sublayers.

**[0047]** In an embodiment, the first passivation layer has a stacked passivation structure of an aluminum oxide layer, a silicon nitride layer and a silicon oxynitride layer sequentially

stacked. The aluminum oxide layer has a thickness ranging from 2 nm to 10 nm, the aluminum oxide layer has a refractive index ranging from 1.5 to 1.8, the silicon nitride layer has a thickness ranging from 40 nm to 80 nm, the silicon nitride layer has a refractive index ranging from 1.9 to 2.3, the silicon oxynitride layer has a thickness ranging from 10 nm to 60 nm, and the silicon oxynitride layer has a refractive index ranging from 1.5 to 1.75.

**[0048]** Further, the rear surface of the semiconductor substrate 10 has a first texture structure 12. The first texture structure 12 may be formed by alkali polishing.

**[0049]** As an optional technical solution of the present disclosure, FIG. 3 is an electron microscope picture of the first texture structure 12 on the rear surface of the semiconductor substrate of the solar cell according to an embodiment of the present disclosure. As shown in FIG. 3, the first texture structure 12 includes two or more first substructures 121 at least partially stacked on one another. The first texture structure 12 presents a non-pyramid-shaped microstructure profile. For example, the first texture structure may present a substantially "step" profile, and the first substructure 121 may be regarded as a stair of the "step".

**[0050]** FIG. 4a is a schematic diagram of three layers of first substructures partially stacked, and FIG. 4b is a schematic diagram of two layers of first substructures partially stacked. Reference sign 121a denotes the outermost first substructure in the first texture structure away from the rear surface, and 121b denotes an adjacent first substructure.

**[0051]** For the two or more first substructures 121 at least partially stacked on one another, in a direction away from the rear surface and perpendicular to the rear surface (which may also be understood as "in a stacking direction"), a distance H between a top surface of the outermost first substructure 121a and a top surface of the first substructure 121b adjacent thereto is less than or equal to 2  $\mu\text{m}$ , which may be 2  $\mu\text{m}$ , 1.8  $\mu\text{m}$ , 1.5  $\mu\text{m}$ , 1.2  $\mu\text{m}$ , 1.1  $\mu\text{m}$ , 1.0  $\mu\text{m}$ , 0.8  $\mu\text{m}$ , 0.5  $\mu\text{m}$ , 0.3  $\mu\text{m}$ , 0.2  $\mu\text{m}$ , 0.1  $\mu\text{m}$  or the like. When the distance H is more than 2  $\mu\text{m}$ , the roughness of the first texture structure is excessively large, and the thickness of the tunnel oxide layer 30 formed on the first texture structure is larger, which bring adverse effects to the formation of the tunnel oxide layer with high density and high uniformity, thereby affecting tunneling and passivation effects of the tunnel oxide layer 30. If the roughness of the first texture structure is excessively small, the thickness of the tunnel oxide layer formed on the first texture structure is smaller, which brings adverse effects to the contact with an electrode

paste. In an embodiment, in the direction away from the rear surface and perpendicular to the rear surface, the distance between the top surface of the outermost first substructure 121a and the top surface of the first substructure 121b adjacent thereto ranges from 0.3  $\mu\text{m}$  to 1.2  $\mu\text{m}$ .

**[0052]** It should be noted that, when the three layers of first substructures are stacked, a distance H between a top surface of the first substructure 121a in any layer and a top surface of the first substructure 121b in an adjacent layer is less than or equal to 2  $\mu\text{m}$ .

**[0053]** It is appreciated that, the distance between the top surface of the outermost first substructure 121a and the top surface of the first substructure 121b adjacent thereto is controlled to be less than or equal to 2  $\mu\text{m}$ , so that the roughness of the first texture structure is controlled within a desired range, which helps to improve the uniformity of the tunnel oxide layer formed on the first texture structure, ensure better performance of the tunnel oxide layer formed, further inhibit a high local phosphorus concentration caused by phosphorous diffusion, reduce contact resistivity, improve the open-circuit voltage of the solar cell, and improve the fill factor and photoelectric conversion efficiency.

**[0054]** A one-dimensional size L of the top surface of the outermost first substructure 121a is less than or equal to 45  $\mu\text{m}$ , that is,  $0 < L \leq 45 \mu\text{m}$ . In an embodiment, the one-dimensional size L is within a range of 2  $\mu\text{m}$  to 45  $\mu\text{m}$ . Here, the one-dimensional size L of the top surface may be a length, width, diagonal length or circular diameter of the surface, which is not limited herein. In some embodiments, the one-dimensional size may be an average value of one-dimensional sizes of top surfaces of a plurality of outermost first substructures within a preset range region of the rear surface of the substrate. An average one-dimensional size of the top surface of the outermost first substructure may be 2  $\mu\text{m}$ , 5  $\mu\text{m}$ , 8  $\mu\text{m}$ , 12  $\mu\text{m}$ , 15  $\mu\text{m}$ , 18  $\mu\text{m}$ , 20  $\mu\text{m}$ , 25  $\mu\text{m}$ , 28  $\mu\text{m}$ , 30  $\mu\text{m}$ , 35  $\mu\text{m}$ , 40  $\mu\text{m}$ , 42  $\mu\text{m}$ , 40  $\mu\text{m}$ , 45  $\mu\text{m}$  or the like. For example, an average one-dimensional size of the top surface of the outermost first substructure ranges from 10  $\mu\text{m}$  to 15  $\mu\text{m}$ .

**[0055]** In an embodiment, as shown in FIG. 3, the first texture structure further includes two or more adjacent second substructures 122 that are not stacked, and a one-dimensional size L of a top surface of the second substructure 122 away from the rear surface is less than or equal to 45  $\mu\text{m}$ , that is,  $0 < L \leq 45 \mu\text{m}$ . In an embodiment, the one-dimensional size L of the second substructure 122 is within a range of 2  $\mu\text{m}$  to 45  $\mu\text{m}$ , which may be 2  $\mu\text{m}$ , 5  $\mu\text{m}$ , 8  $\mu\text{m}$ , 12  $\mu\text{m}$ ,

15  $\mu\text{m}$ , 18  $\mu\text{m}$ , 20  $\mu\text{m}$ , 25  $\mu\text{m}$ , 28  $\mu\text{m}$ , 30  $\mu\text{m}$ , 32  $\mu\text{m}$ , 35  $\mu\text{m}$ , 45  $\mu\text{m}$  or the like.

[0056] Different from the pyramid-shaped microstructure of the front surface, the top surface of the first substructure and/or the top surface of the second substructure of the rear surface is a polygonal plane. The polygonal plane is in a shape of at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square and a substantially trapezoid. It shall be understood that, during actual manufacturing process, the top surface of the first substructure or second substructure presents a profile of an irregular polygon plane, and wholly presents a profile of a substantially diamond, a square and a trapezoid.

[0057] In some examples, the manufacturing of subsequent passivation film layers, such as the first passivation layer 20, the tunnel oxide layer 30 and the doped conductive layer 40, may damage original structures of the second texture structure and the first texture structure to some extent. For example, in a mass-produced solar cell, the second texture structure may also include a small number of non-pyramid-shaped microstructures formed due to the damages to the spires of the pyramid-shaped microstructures.

[0058] In some examples, when a texture size representing the second texture structure or the first texture structure of the solar cell is measured, such as the one-dimensional size of the top surface of the first substructure and the distance between the surfaces of adjacent first substructures, surfaces of the film layers are directly measured for calibration through a test instrument (an optical microscope, an atomic force microscope, a scanning electron microscope, a transmission electron microscope, or the like). In one case, since the thickness of the film layer is in nanoscale, it can be obtained directly using film layer measurement data corresponding to the second texture structure or the first texture structure, and the film layer measurement data is a sum of the thickness of the film layer and a texture size. In another case, it can also be obtained by subtracting film layer thickness data from the film layer measurement data. The above measurement means are only examples and are not limited in the present disclosure.

[0059] As shown in FIG. 1 and FIG. 6, the tunnel oxide layer 30 located on the first texture structure 12 of the rear surface of the semiconductor substrate 10 may have a stacking structure of one or more of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer and a hafnium oxide layer. In other embodiments, the tunnel oxide

layer 30 may also be an oxygen-containing silicon nitride layer, an oxygen-containing silicon carbide layer or the like. The tunnel oxide layer 30 has a thickness ranging from 0.8 nm to 2 nm. For example, the thickness of the tunnel oxide layer 30 is 0.8 nm, 0.9 nm, 1.0 nm, 1.2 nm, 1.4 nm, 1.6 nm, 1.8 nm, 2 nm or the like. The thickness of the tunnel oxide layer 30 refers to a thickness of the tunnel oxide layer relative to a formation surface. The thickness of the tunnel oxide layer 30 formed on the first texture structure can be calculated by taking a normal direction of an inclined surface of the substructure as a thickness direction and observing a cross section thereof. When the thickness of the tunnel oxide layer 30 is excessively large, it may bring adverse effects to reducing the contact resistance of the tunnel oxide layer. A decrease in the fill factor caused by the contact resistance can be inhibited by controlling the thickness of the tunnel oxide layer.

**[0060]** In an embodiment, a band gap width of the tunnel oxide layer 30 is greater than 3.0 eV, and it is generally difficult to transport carriers through the tunnel oxide layer 30 by thermal emission. However, the tunnel oxide layer 30 is very thin and carriers can pass through the tunnel oxide layer 30 through a tunnel effect, so the tunnel oxide layer having a thickness within a range of 0.8 nm to 2nm does not block the transport of most carriers. As the thickness of the tunnel oxide layer gradually increases, the tunnel effect of most carriers is affected, and it is difficult to transport the carriers through the tunnel oxide layer 30, and the photoelectric conversion efficiency of the solar cell may gradually decrease. When the thickness of the tunnel oxide layer is excessively small, the tunnel oxide layer cannot perform the passivation effect. As a result, in an embodiment, the tunnel oxide layer 30 is a silicon oxide layer, and the tunnel oxide layer 30 has a thickness ranging from 0.8 nm to 1.5 nm.

**[0061]** As an optional technical solution of the present disclosure, as shown in FIG. 6, a thickness D1 of the tunnel oxide layer on the top surface of the outermost first substructure is less than a thickness D2 of the tunnel oxide layer on a side surface of the outermost first substructure. For example, a thickness difference (D2-D1) between the tunnel oxide layer on the top surface of the outermost first substructure and the tunnel oxide layer on a side surface of the outermost substructure is less than or equal to 0.15 nm. The thickness difference may be 0.14 nm, 0.13 nm, 0.12 nm, 0.11 nm, 0.10 nm, 0.09 nm, 0.08 nm, 0.07 nm, 0.06 nm, 0.05 nm, 0.04 nm or the like. When the tunnel oxide layer on the top surface of the outermost first

substructure and the tunnel oxide layer on the side surface of the outermost substructure are excessively large, the thickness of the tunnel oxide layer has poor uniformity, a current density of the solar cell is easily affected, and the open-circuit voltage of the solar cell decreases.

**[0062]** In some embodiments, texture structures with different profiles are arranged on the front and rear surfaces of the semiconductor substrate, a pyramidal texture structure is formed on the front surface, and a non-pyramidal texture structure is formed on the rear surface, so that the solar cell formed has a light trap structure at different levels, which increases an effective contact area of light. Moreover, for the first texture structure formed on the rear surface, the distance between the top surface of the outermost first substructure and the top surface of the first substructure adjacent thereto is controlled within 2  $\mu\text{m}$ , which helps to reduce a pinhole in the tunnel oxide layer and then improves the density and uniformity of the tunnel oxide layer, further inhibit a high local doping concentration of the doped conductive layer on the surface of the tunnel oxide layer, reduce contact resistivity, improve the open-circuit voltage of the solar cell, and improve the fill factor and photoelectric conversion efficiency.

**[0063]** In some embodiments, the doped conductive layer 40 may be a doped polycrystalline silicon layer, a doped microcrystalline silicon layer or a doped amorphous silicon layer. The doped conductive layer 40 and the semiconductor substrate have doping elements of a same conductivity type.

**[0064]** When the semiconductor substrate 10 is an N-type monocrystalline silicon, the doped conductive layer 40 is an N-type doped polycrystalline silicon layer, an N-type doped microcrystalline silicon layer or an N-type doped amorphous silicon layer, and the doping element may be an N-type doping element such as phosphorus.

**[0065]** In some embodiments, the doped conductive layer 40 has a thickness ranging from 60 nm to 200 nm. For example, as an N-type doped polycrystalline silicon layer, the doped conductive layer 40 may have a refractive index ranging from 3.5 to 4.5.

**[0066]** As an optional technical solution of the present disclosure, the second passivation layer 50 includes at least one of a silicon nitride layer, a silicon oxide layer and a silicon oxynitride layer. The second passivation layer 50 has a thickness ranging from 70 nm to 120 nm. For example, the second passivation layer 50 is a silicon nitride layer. The silicon nitride layer has a low silicon to nitrogen ratio, and the silicon nitride layer has a refractive index

ranging from 1.7 to 2.1, which may be 1.7, 1.8, 1.9, 2.0, 2.1 or the like, and may also be other values in the above range, and is not limited herein. The refractive index of the silicon nitride layer is controlled to enable the silicon nitride layer to have low silicon to nitrogen ratio, so that contact resistivity can be reduced during metallization of the second passivation layer 50 formed, so as to further reduce the contact resistivity of the solar cell.

**[0067]** In some embodiments, when the second passivation layer 50 has a stacking structure of a silicon nitride layer and a silicon oxide layer or a stacking structure of a silicon nitride layer and a silicon oxynitride layer, the silicon nitride layer is located on a surface of the doped conductive layer, and the silicon oxide layer or the silicon oxynitride layer is located on a surface of the silicon nitride layer.

**[0068]** Further, the solar cell further includes a first electrode 60 and a second electrode 70. The first electrode 60 passes through the first passivation layer 20 to form ohmic contact with the P-type doped layer (for example, the boron-doped diffusion layer) on the front surface of the semiconductor substrate 10. The second electrode 70 passes through the second passivation layer 50 to form ohmic contact with the doped conductive layer 40. The doped conductive layer 40 and the tunnel oxide layer 30 form a passivated contact structure. The first electrode 60 and the second electrode 70 may be formed by sintering a metal conductive paste coated on surfaces of the first passivation layer and the second passivation layer. In some embodiments, the first electrode 60 or the second electrode 70 is made of a metal material such as silver, aluminum, copper or nickel.

**[0069]** For the solar cell formed as shown in FIG. 1, that is, the second texture structure of the pyramid-shaped microstructure formed on the front surface of the semiconductor substrate 10, the first texture structure of the non-pyramid-shaped microstructure formed on the rear surface of the semiconductor substrate, the first passivation layer 20 (for example, a stacked passivation structure of an aluminum oxide layer and a silicon nitride layer) formed on the second texture structure, and the tunnel oxide layer 30, the doped conductive layer 40 and the second passivation layer 50 (for example, a silicon nitride layer) matching one another formed on the first texture structure. The solar cell structure formed as above has higher photoelectric conversion efficiency.

**[0070]** In a second aspect, an embodiment of the present disclosure provides a photovoltaic

module including a plurality of solar cell strings.

**[0071]** As shown in FIG. 7a and FIG. 7b, the photovoltaic module includes a first cover plate 1, a first packaging adhesive layer 2, a solar cell string 3, a second packaging layer 4 and a second cover plate 5.

5 **[0072]** The solar cell string 3 includes a plurality of solar cells (the solar cell as shown in FIG. 1) that are connected through a conductive band (not shown). The solar cells may be connected by partial stacking or by splicing.

**[0073]** The first cover plate 1 and the second cover plate 5 are transparent or opaque cover plates, such as glass cover plates or plastic cover plates.

10 **[0074]** Two sides of the first packaging adhesive layer 2 contact and are bonded to the first cover plate 1 and the solar cells 3, respectively, and two sides of the second packaging layer 2 are contact and are bonded to the second cover plate 1 and the solar cells 3, respectively. The first packaging adhesive layer 2 and the second packaging layer 4 may be ethylene-vinyl acetate copolymer (EVA) film, a polyolefin elastomer (POE) film or a polyethylene terephthalate (PET) film, respectively.

**[0075]** Side edges of the photovoltaic module may also be completely packaged, that is, the side edges of the photovoltaic module are fully packaged with a packaging adhesive tape to prevent a stacking deviation during the stacking of the photovoltaic module.

**[0076]** Further, the photovoltaic module (the photovoltaic module 100 shown in FIG. 7b) further includes an edge sealing member 6 fixedly packaged to a partial edge of the photovoltaic module. As shown in FIG. 7b, the edge sealing member 6 is fixedly packaged to an edge of the photovoltaic module near a corner. The edge sealing member 6 may be a high-temperature resistant tape. The high-temperature resistant tape has excellent high-temperature resistance and may not decompose or fall off during the stacking, which can ensure the reliable packaging of the photovoltaic module. Two ends of the high-temperature resistant tape are fixed to the second cover plate 5 and the first cover plate 1, respectively. The two ends of the high-temperature resistant tape may be bonded to the second cover 5 and the first cover 1, respectively, and the middle thereof can limit a side edge of the photovoltaic module to prevent a stacking deviation of the photovoltaic module during the stacking.

30 **[0077]** In a third aspect, the present disclosure further provides a method for manufacturing

a solar cell for manufacturing the solar cell described above. As shown in FIG. 8, the method includes the following steps.

**[0078]** In S10, a semiconductor substrate is textured, and a second texture structure is formed on a front surface of the semiconductor substrate, the second texture structure includes a pyramid-shaped microstructure.

**[0079]** In S20, the front surface of the textured semiconductor substrate is doped to form a doped layer.

**[0080]** In S30, a rear surface of the semiconductor substrate is polished with an alkali solution, so that a first texture structure is formed on the rear surface of the semiconductor substrate, the first texture structure includes two or more first substructures at least partially stacked, for the two or more first substructures at least partially stacked, in a direction away from the rear surface and perpendicular to the rear surface, a distance between a top surface of the outermost first substructure and a top surface of the first substructure adjacent thereto is less than or equal to 2  $\mu\text{m}$ , and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ .

**[0081]** In S40, a tunnel oxide layer is formed on the first texture structure of the rear surface of the semiconductor substrate.

**[0082]** In S50, a polycrystalline silicon layer is formed on a surface of the tunnel oxide layer, and the polycrystalline silicon layer is doped to form a doped conductive layer, the doped conductive layer and the semiconductor substrate having doping elements of a same conductivity type.

**[0083]** In S60, a first passivation layer is formed on the front surface of the semiconductor substrate.

**[0084]** In S70, a second passivation layer is formed on a surface of the doped conductive layer.

**[0085]** In the above solution, the rear surface of the semiconductor substrate is polished with an alkali solution, so that texture structures with different profiles are formed on the front and rear surfaces of the semiconductor substrate. A pyramidal texture structure is formed on the front surface, and a non-pyramidal texture structure is formed on the rear surface, so that the solar cell formed has a light trap structure at different levels, which increases an effective

contact area of light. Moreover, for the first texture structure formed on the rear surface, the distance between the top surface of the outermost first substructure and the top surface of the first substructure adjacent thereto is controlled within 2  $\mu\text{m}$ , which helps to reduce a pinhole in the tunnel oxide layer and then improve the density and uniformity of the tunnel oxide layer, further inhibit a high local doping concentration of the doped conductive layer on the surface of the tunnel oxide layer, reduce contact resistivity, improve the open-circuit voltage of the solar cell, and improve the fill factor and photoelectric conversion efficiency.

**[0086]** The solution is described in detail as follows.

**[0087]** In S10, a semiconductor substrate is textured, and a second texture structure is formed on a front surface of the semiconductor substrate, the second texture structure includes a pyramid-shaped microstructure.

**[0088]** The semiconductor substrate may be a crystalline silicon substrate, which is, for example, one of a polycrystalline silicon substrate, a monocrystalline silicon substrate, a microcrystalline silicon substrate and a silicon carbide substrate. A specific type of the semiconductor substrate is not limited in the embodiments of the present disclosure. In some embodiments, the semiconductor substrate is an N-type crystalline silicon substrate (or silicon wafer). The semiconductor substrate has a thickness ranging from 60  $\mu\text{m}$  to 240  $\mu\text{m}$ , which may be 60  $\mu\text{m}$ , 80  $\mu\text{m}$ , 90  $\mu\text{m}$ , 100  $\mu\text{m}$ , 120  $\mu\text{m}$ , 150  $\mu\text{m}$ , 200  $\mu\text{m}$ , 240  $\mu\text{m}$  or the like. The doping elements of the semiconductor substrate may be phosphorus, nitrogen and the like.

**[0089]** It shall be noted that the present disclosure does not limit how the texturing is performed. For example, an N-type substrate may be textured using, but not limited to, a wet texturing process. When the N-type semiconductor substrate is an N-type crystalline silicon substrate, the texturing may be performed using an alkaline solution such as a potassium hydroxide solution. Since the corrosion of the NaOH solution is anisotropic, a pyramid-shaped microstructure can be manufactured.

**[0090]** As shown in FIG. 2, the front surface of the semiconductor substrate 10 has a second texture structure 11, and the second texture structure 11 includes a pyramid-shaped microstructure 111. The pyramid-shaped microstructure 111 may have a structure of a tetrahedron, a substantially tetrahedron, a pentahedron, a substantially pentahedron, or the like. The pyramid-shaped microstructure 111 may be formed by texturing the semiconductor

substrate. The texturing may be chemical etching, laser etching, a mechanical process, plasma etching, or the like. The pyramid-shaped microstructure enables a metal paste to better fill the microstructure when the metal paste forms an electrode by screen printing, to obtain better electrode contact, which can effectively reduce series resistance of the solar cell, and improve the fill factor.

**[0091]** In S20, the front surface of the textured semiconductor substrate is doped to form a doped layer.

**[0092]** In an embodiment, when the semiconductor substrate 10 is an N-type substrate, a P-type doped layer may be formed on the front surface of the semiconductor substrate by one or more of the processes of high temperature diffusion, slurry doping, and ion implantation, so as to form a PN junction in the semiconductor substrate 10.

**[0093]** In some embodiments, the P-type doped layer is a boron-doped diffusion layer. The boron-doped diffusion layer is a P-type doped layer (i.e., P+ layer) formed by using a boron source to diffuse boron atoms to a certain depth on the front surface through a diffusion process. For example, the boron source may be liquid boron tribromide. A microcrystalline silicon phase of the substrate after boron diffusion treatment is transformed into a polycrystalline silicon phase. Since the surface of the semiconductor substrate has a high concentration of boron, a borosilicate glass (BSG) layer is generally formed.

**[0094]** Further, in S30, prior to the step of polishing a rear surface of the semiconductor substrate with an alkali solution, the method further includes: removing the borosilicate glass layer from the rear surface of the semiconductor substrate with a prepared mixed acid, the mixed acid includes hydrogen fluoride having a mass fraction of 0.1% to 10%, sulfuric acid having a mass fraction of 10% to 20% and nitric acid having a mass fraction of 25% to 50%; and washing and drying the rear surface of the semiconductor substrate after pickling.

**[0095]** During the boron diffusion treatment, the rear surface of the semiconductor substrate is coated to form part of the borosilicate glass, which shall be removed. It shall be noted that a porous structure may appear on the rear surface of the semiconductor substrate after pickling.

**[0096]** In an embodiment, a pickling time ranges from 10 seconds to 180 seconds, and a pickling temperature ranges from 7°C to 20°C, that is, the borosilicate glass on the rear surface of the semiconductor substrate is removed by pickling at room temperature to expose a body of

the semiconductor substrate.

**[0097]** In S30, the rear surface of the semiconductor substrate is polished with the alkali solution, so that a first texture structure is formed on the rear surface of the semiconductor substrate.

5 **[0098]** In an embodiment, the rear surface of the semiconductor substrate is cleaned with the alkali solution having a mass fraction of 5% to 15% to remove porous silicon.

**[0099]** Micro-liquid droplets of the alkali solution are dropped by spraying to the rear surface of the semiconductor substrate for roughening treatment, and then pre-cleaning is performed with a hydrofluoric acid having a mass fraction of 5% to 10%.

10 **[00100]** The rear surface of the semiconductor substrate is polished with a polishing liquid at a polishing temperature ranging from 70°C to 80°C for a polishing time less than 260 seconds. The polishing liquid includes NaOH having a mass fraction of 1% to 15%, KOH having a mass fraction of 1% to 15% and an additive having a mass fraction of 0.5% to 2.5%. Here, the polishing liquid may be designated as the etching solution.

15 **[00101]** Organic components in the etching solution are removed by a mixture of potassium hydroxide having a mass fraction of 5% to 15% and hydrogen peroxide having a mass fraction of 15% to 40%.

**[00102]** The polished semiconductor substrate is washed and dried.

**[00103]** In some embodiments, when the rear surface is polished, the borosilicate glass layer  
20 on the front surface of the semiconductor substrate shall be protected, for example, by a mask.

**[00104]** In an embodiment, due to the low boron concentration on the rear surface of the semiconductor substrate, the etching efficiency can be improved effectively by using the alkali solution. The alkali solutions contain organic bases and/or inorganic bases. The inorganic bases may be NaOH, KOH,  $\text{Ga}(\text{OH})_2$ ,  $\text{NH}_3 \cdot \text{H}_2\text{O}$ , and the organic bases may be triethylamine,  
25 nitrophenol, pyridine, quinine, colchicine, and the like. The additive in the polishing liquid may be a buffer solution composed of sodium sulfonate, maleic anhydride, alkyl glycoside, and the like.

**[00105]** The polishing temperature may be 70°C, 72°C, 74°C, 75°C, 78°C, 79°C, 80°C or the like, and the polishing time may be 250 seconds, 240 seconds, 230 seconds, 220 seconds, 200  
30 seconds, 180 seconds, 160 seconds, 140 seconds, 120 seconds, 100 seconds, 80 seconds or the

like, which may also be other values in the above ranges.

**[00106]** In some embodiments, a polishing weight loss of the semiconductor substrate is less than 0.3 g.

**[00107]** A shape of the substructure in the first texture structure after polishing may be adjusted by controlling the polishing time and the polishing temperature, so that in the two or more first substructures at least partially stacked a distance between a top surface of the outermost first substructure and a top surface of the first substructure adjacent thereto is less than or equal to 2  $\mu\text{m}$  in a direction away from the rear surface and perpendicular to the rear surface, so as to increase the roughness of the rear surface of the semiconductor substrate.

**[00108]** In some embodiments, the first texture structure including a non-pyramid-shaped microstructure may be formed by hot-air drying the surface of the semiconductor substrate.

**[00109]** As an optional technical solution of the present disclosure, FIG. 3 is an electron microscope picture of the first texture structure 12 on the rear surface of the semiconductor substrate of the solar cell according to an embodiment of the present disclosure. As shown in FIG. 3, the first texture structure 12 includes two or more first substructures 121 at least partially stacked.

**[00110]** FIG. 4a is a schematic diagram of three layers of first substructures partially stacked, and FIG. 4b is a schematic diagram of two layers of first substructures partially stacked. Reference sign 121a denotes the outermost first substructure in the first texture structure away from the rear surface, and 121b denotes the innermost first substructure in the first texture structure close to the rear surface.

**[00111]** For the two or more first substructures 121 at least partially stacked, in the direction away from the rear surface and perpendicular to the rear surface, a distance H between a top surface of the outermost first substructure 121a and a top surface of the first substructure 121b adjacent thereto is less than or equal to 2  $\mu\text{m}$ , which may be 2  $\mu\text{m}$ , 1.8  $\mu\text{m}$ , 1.5  $\mu\text{m}$ , 1.2  $\mu\text{m}$ , 1.1  $\mu\text{m}$ , 1.0  $\mu\text{m}$ , 0.8  $\mu\text{m}$ , 0.5  $\mu\text{m}$ , 0.3  $\mu\text{m}$ , 0.2  $\mu\text{m}$ , 0.1  $\mu\text{m}$  or the like. When the distance H is more than 2  $\mu\text{m}$ , the roughness of the first texture structure is excessively large, and the thickness of the tunnel oxide layer 30 formed on the first texture structure is larger, which brings adverse effects to the formation of the tunnel oxide layer with high density and high uniformity, thereby affecting tunneling and passivation effects of the tunnel oxide layer 30. If the roughness

of the first texture structure is excessively small, the thickness of the tunnel oxide layer formed on the first texture structure is smaller, which brings adverse effects to the contact with an electrode paste. As a result, in an embodiment, in the direction away from the rear surface and perpendicular to the rear surface, the distance between the top surface of the outermost first substructure 121a and the top surface of the first substructure 121b adjacent thereto ranges from 0.3  $\mu\text{m}$  to 1.2  $\mu\text{m}$ .

**[00112]** It shall be noted that, when the three layers of first substructures are stacked, a distance H between a top surface of the first substructure 121a in any layer and a top surface of the first substructure 121b in an adjacent layer is less than or equal to 2  $\mu\text{m}$ .

**[00113]** The distance between the top surface of the outermost first substructure 121a and the top surface of the first substructure 121b adjacent thereto is controlled to be less than or equal to 2  $\mu\text{m}$ , so that the roughness of the first texture structure is controlled within a desired range, which helps to improve the uniformity of the tunnel oxide layer formed on the first texture structure, ensure better performance of the tunnel oxide layer formed, further inhibit a high local phosphorus concentration caused by phosphorous diffusion, reduce contact resistivity, improve the open-circuit voltage of the solar cell, and improve the fill factor and photoelectric conversion efficiency.

**[00114]** A one-dimensional size L of the top surface of the outermost first substructure 121a is less than or equal to 45  $\mu\text{m}$ . In an embodiment, the one-dimensional size L is within a range of 2  $\mu\text{m}$  to 45  $\mu\text{m}$ . Here, the one-dimensional size L of the top surface may be a length, width, diagonal length or circular diameter of the surface, which is not limited herein. In some embodiments, the one-dimensional size may be an average value of one-dimensional sizes of top surfaces of a plurality of outermost first substructures within a preset range region of the rear surface of the substrate. An average one-dimensional size of the top surface of the outermost first substructure may be 2  $\mu\text{m}$ , 5  $\mu\text{m}$ , 8  $\mu\text{m}$ , 12  $\mu\text{m}$ , 15  $\mu\text{m}$ , 18  $\mu\text{m}$ , 20  $\mu\text{m}$ , 25  $\mu\text{m}$ , 28  $\mu\text{m}$ , 30  $\mu\text{m}$ , 35  $\mu\text{m}$ , 40  $\mu\text{m}$ , 42  $\mu\text{m}$ , 40  $\mu\text{m}$ , 45  $\mu\text{m}$  or the like. For example, an average one-dimensional size of the top surface of the outermost first substructure ranges from 10  $\mu\text{m}$  to 15  $\mu\text{m}$ .

**[00115]** In an embodiment, as shown in FIG. 3, the first texture structure further includes two or more adjacent second substructures 122 not stacked, and a one-dimensional size L of a

top surface of the second substructure 122 away from the rear surface is less than or equal to 45  $\mu\text{m}$ . In an embodiment, the one-dimensional size L of the first substructure 122 is within a range of 2  $\mu\text{m}$  to 45  $\mu\text{m}$ , which may be 2  $\mu\text{m}$ , 5  $\mu\text{m}$ , 8  $\mu\text{m}$ , 12  $\mu\text{m}$ , 15  $\mu\text{m}$ , 18  $\mu\text{m}$ , 20  $\mu\text{m}$ , 25  $\mu\text{m}$ , 28  $\mu\text{m}$ , 30  $\mu\text{m}$ , 32  $\mu\text{m}$ , 35  $\mu\text{m}$ , 45  $\mu\text{m}$  or the like.

5 **[00116]** Different from the typical pyramid-shaped microstructure of the front surface, the top surface of the first substructure and/or the top surface of the second substructure of the rear surface is a polygonal plane. The polygonal plane is in a shape of at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square and a substantially trapezoid. It shall be understood that, during actual manufacturing, the top surface of the first substructure  
10 or second substructure presents a profile of an irregular polygon plane, and presents in entirety a profile of a substantially diamond, a square and a trapezoid.

**[00117]** In S40, a tunnel oxide layer is formed on the first texture structure of the rear surface of the semiconductor substrate.

**[00118]** In some embodiments, the rear surface of the semiconductor substrate may be etched  
15 and then treated by ozone oxidation, high temperature thermal oxidation, nitric acid oxidation, chemical vapor deposition and low-pressure chemical vapor deposition to form the tunnel oxide layer 30.

**[00119]** In some embodiments, the tunnel oxide layer 30 is deposited on the rear surface of the semiconductor substrate by a temperature change process and chemical vapor deposition.  
20 During the deposition, a heating rate is controlled to range from 0.5°C/min to 3°C/min, a deposition temperature is controlled to range from 560°C to 620°C and a deposition time is controlled to range from 3 min to 10 min.

**[00120]** For example, during the deposition, the deposition temperature may be 560°C, 570°C, 580°C, 590°C, 600°C, 610°C, 615°C, 620°C or the like, the deposition time may be 3  
25 min, 4 min, 5 min, 6 min, 7 min, 8 min, 9 min, 10 min or the like, and the heating rate may be 0.5 °C/min, 0.8 °C/min, 1.0 °C/min, 1.2 °C/min, 1.5 °C/min, 2.0 °C/min, 2.5 °C/min, 3 °C/min or the like, which may also be other values in the above ranges and are not limited herein.

**[00121]** The tunnel oxide layer 30 is deposited on the rear surface of the semiconductor substrate by low-pressure chemical vapor deposition, which can reduce the influence of a high  
30 local doping concentration of the thinner tunnel oxide layer 30 in subsequent high temperature

doping treatment and reduce the fluctuation of the open-circuit voltage. The tunnel oxide layer 30 formed by the temperature change process and low-pressure chemical vapor deposition can increase the open-circuit voltage of the solar cell by 4 mV to 6 mV.

**[00122]** The tunnel oxide layer 30 may have a stacking structure of one or more of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer and a hafnium oxide layer. In other embodiments, the tunnel oxide layer 30 may also be an oxygen-containing silicon nitride layer, an oxygen-containing silicon carbide layer or the like. The tunnel oxide layer 30 has a thickness ranging from 0.8 nm to 2 nm. For example, the thickness of the tunnel oxide layer 30 is 0.8 nm, 0.9 nm, 1.0 nm, 1.2 nm, 1.4 nm, 1.6 nm, 1.8 nm, 2 nm or the like. The thickness of the tunnel oxide layer 30 refers to a thickness of the tunnel oxide layer relative to a formation surface. The thickness of the tunnel oxide layer 30 formed on the first texture structure can be calculated by taking a normal direction of an inclined surface of the substructure as a thickness direction and observing a cross section thereof. When the thickness of the tunnel oxide layer 30 is excessively large, it brings adverse effects to reducing the contact resistance of the tunnel oxide layer. A decrease in the fill factor caused by the contact resistance can be inhibited by controlling the thickness of the tunnel oxide layer.

**[00123]** A band gap width of the tunnel oxide layer 30 is greater than 3.0 eV, and it is generally difficult to transport carriers through the tunnel oxide layer 30 by thermal emission. However, the tunnel oxide layer 30 is very thin and carriers can pass through the tunnel oxide layer 30 through a tunnel effect, so the tunnel oxide layer having a thickness within a range of 0.8 nm to 2nm does not block the transport of most carriers. As the thickness of the tunnel oxide layer gradually increases, the tunnel effect of most carriers is affected, and it is difficult to transport the carriers through the tunnel oxide layer 30, and the photoelectric conversion efficiency of the solar cell may gradually decrease. When the thickness of the tunnel oxide layer is excessively small, the tunnel oxide layer cannot have a passivation effect. As a result, in an embodiment, the tunnel oxide layer 30 is a silicon oxide layer, and the tunnel oxide layer 30 has a thickness ranging from 0.8 nm to 1.5 nm.

**[00124]** As an optional technical solution of the present disclosure, as shown in FIG. 6, a thickness D1 of the tunnel oxide layer on the top surface of the outermost first substructure is less than a thickness D2 of the tunnel oxide layer on a side surface of the outermost first

substructure. A thickness difference (D2-D1) between the tunnel oxide layer on the top surface of the outermost first substructure and the tunnel oxide layer on a side surface of the outermost substructure is less than or equal to 0.15 nm. The thickness difference may be 0.14 nm, 0.13 nm, 0.12 nm, 0.11 nm, 0.10 nm, 0.09 nm, 0.08 nm, 0.07 nm, 0.06 nm, 0.05 nm, 0.04 nm or the like. When the tunnel oxide layer on the top surface of the outermost first substructure and the tunnel oxide layer on the side surface of the outermost substructure are excessively large, the thickness of the tunnel oxide layer has poor uniformity, a current density of the solar cell may be affected, and the open-circuit voltage of the solar cell decreases.

5  
10 **[00125]** In S50, a polycrystalline silicon layer is formed on a surface of the tunnel oxide layer, and the polycrystalline silicon layer is doped to form a doped conductive layer, a conductivity type of the doped conductive layer is the same as that of the semiconductor substrate.

**[00126]** In some embodiments, the polycrystalline silicon layer is deposited on the surface of the tunnel oxide layer by any one of physical vapor deposition, chemical vapor deposition, plasma enhanced chemical vapor deposition and atomic layer deposition. The chemical vapor deposition may be low-pressure chemical vapor deposition or atmospheric chemical vapor deposition.

15  
20 **[00127]** In an embodiment, the deposition of the tunnel oxide layer and the polycrystalline silicon layer and the doping of the polycrystalline silicon layer are all performed in a low-pressure chemical vapor deposition device.

**[00128]** Firstly, the alkali-polished semiconductor substrate is placed in a deposition device, an oxygen source (e.g. oxygen, nitrous oxide, or ozone) of 20 L to 60 L is introduced, and the deposition device is heated to 560°C to 620°C according to a heating rate ranging from 0.5 °C/min to 3 °C/min for a deposition time ranging from 3 min to 10 min to form the tunnel oxide layer 30.

25  
**[00129]** After the introduction of the oxygen, a constant temperature phase is reached, and then an appropriate amount of silane is introduced to form a polycrystalline silicon layer.

**[00130]** Finally, the polycrystalline silicon layer is doped in situ to form the doped conductive layer 40.

30 **[00131]** In some embodiments, the doped conductive layer 40 may be a doped

polycrystalline silicon layer. The doped conductive layer 40 and the semiconductor substrate have doping elements of a same conductivity type.

5     **[00132]**     In other embodiments, a microcrystalline silicon layer or an amorphous silicon layer may also be deposited on the surface of the tunnel oxide layer 30 and doped in situ to form a doped microcrystalline silicon layer or doped amorphous silicon layer, that is, the doped conductive layer 40.

10     **[00133]**     When the semiconductor substrate 10 is an N-type monocrystalline silicon, the doped conductive layer 40 is an N-type doped polycrystalline silicon layer, an N-type doped microcrystalline silicon layer or an N-type doped amorphous silicon layer, and the doping element may be an N-type doping element such as phosphorus.

15     **[00134]**     In some embodiments, the doped conductive layer 40 has a thickness ranging from 60 nm to 200 nm. For example, as an N-type doped polycrystalline silicon layer, the doped conductive layer 40 has a refractive index ranging from 3.5 to 4.5.

20     **[00135]**     Subsequent to S50 and prior to S60, the method further includes: performing high-temperature annealing treatment and cleaning treatment after the doped polycrystalline silicon layer is deposited in situ.

25     **[00136]**     Embodiments of the present disclosure does not limit how the high-temperature annealing treatment and the cleaning treatment are performed. Illustratively, the high-temperature annealing treatment deals with the deposited polycrystalline silicon layer, which enables the polycrystalline silicon layer to better crystalize. An annealing temperature ranges from 700°C to 1000°C.

30     **[00137]**     Through the high-temperature annealing treatment, diffused pentavalent phosphorus atoms form the doped polycrystalline silicon layer. After the annealing treatment, a microcrystalline silicon phase of the crystalline silicon is transformed into a polycrystalline silicon phase, and phosphorus is deposited on the surface of the semiconductor substrate to form phosphorosilicate glass (PSG).

35     **[00138]**     The cleaning treatment is intended to remove a phosphorosilicate glass (PSG) layer formed during the phosphorus doping. Due to the high concentration of phosphorus on the surface of the semiconductor substrate, a phosphorosilicate glass (PSG) layer is generally formed during phosphorus diffusion. This phosphorosilicate glass layer has a metal impurity

absorption effect, may adversely affect the normal operation of the solar cell, and shall be removed.

5 **[00139]** In an embodiment, the rear surface of the semiconductor substrate may be placed downward in a chain pickling device (the chain device is at a tape speed of 1.0 /min to 2.0 m/min). The semiconductor substrate enters an acid tank to etch away the phosphorosilicate glass (PSG) layer formed on the rear surface by phosphorus diffusion. The acid tank is provided with a prepared mixed acid. The mixed acid includes hydrogen fluoride with a mass concentration of 2% to 10% and hydrogen chloride with a mass concentration of 2% to 10%. A pickling temperature ranges from 15°C to 25°C, and a pickling time ranges from about 30  
10 seconds to 60 seconds. The front surface of the semiconductor substrate is covered with a water film, and the borosilicate glass (BSG) layer on the front surface of the semiconductor substrate may also be used as a protective layer. During the removal of the phosphorosilicate glass (PSG) layer, reaction of the front surface of the semiconductor substrate with the mixed acid is prevented.

15 **[00140]** It shall be noted that a washing process is needed after the pickling. A washing time ranges from 10 seconds to 20 seconds, and a washing temperature may range from 15°C to 25°C. In an embodiment, the semiconductor substrate may also be dried after washing.

**[00141]** In S60, a first passivation layer is formed on the front surface of the semiconductor substrate.

20 **[00142]** In some embodiments, the first passivation layer 20 may be deposited by plasma enhanced chemical vapor deposition. It is appreciated that, other methods such as organic chemical vapor deposition may also be used. Embodiments of the present disclosure does not limit implementations of the first passivation layer 20.

**[00143]** The first passivation layer 20 may have, but is not limited to, a monolayer or  
25 laminated structure of a silicon nitride layer, a silicon oxynitride layer, a silicon oxide layer and the like. It is appreciated that, the first passivation layer may also be other types of passivation layers. The present disclosure does not limit a specific material of the first passivation layer. For example, in other embodiments, the first passivation layer may also have a stacked structure of silicon dioxide and silicon nitride. The first passivation layer can have a good passivation  
30 effect on the semiconductor substrate, which helps to improve the conversion efficiency of the

solar cell.

**[00144]** In S70, a second passivation layer is formed on a surface of the doped conductive layer.

5 **[00145]** The second passivation layer 50 may be deposited by plasma enhanced chemical vapor deposition. It is appreciated that, other methods such as organic chemical vapor deposition may also be used. Embodiments of the present disclosure does not limit implementations of the second passivation layer 50.

10 **[00146]** As an optional technical solution of the present disclosure, the second passivation layer 50 includes at least one of a silicon nitride layer, a silicon oxide layer and a silicon oxynitride layer. The second passivation layer 50 has a thickness ranging from 70 nm to 120 nm. For example, the second passivation layer 50 is a silicon nitride layer. The silicon nitride layer has a low silicon to nitrogen ratio, and the silicon nitride layer has a refractive index ranging from 1.7 to 2.1, which may be 1.7, 1.8, 1.9, 2.0, 2.1 or the like, and may also be other values in the above range, which is not limited herein. The refractive index of the silicon nitride layer is controlled to enable the silicon nitride layer to possess low silicon to nitrogen ratio, so  
15 that contact resistivity can be reduced during metallization of the second passivation layer 50 formed, so as to further reduce the contact resistivity of the solar cell.

**[00147]** In some embodiments, when the second passivation layer 50 has a stacking structure of a silicon nitride layer and a silicon oxide layer or a stacking structure of a silicon nitride layer  
20 and a silicon oxynitride layer, the silicon nitride layer is located on a surface of the doped conductive layer, and the silicon oxide layer or the silicon oxynitride layer is located on a surface of the silicon nitride layer.

**[00148]** Further, subsequent to S70, the method further includes: screen-printing and sintering the semiconductor substrate to form an electrode.

25 **[00149]** In some embodiments, the solar cell further includes a first electrode 60 and a second electrode 70. The first electrode 60 passes through the first passivation layer 20 to form ohmic contact with the P-type doped layer (for example, the boron-doped diffusion layer) on the front surface of the semiconductor substrate 10. The second electrode 70 passes through the second passivation layer 50 to form ohmic contact with the doped conductive layer 40. The doped  
30 conductive layer 40 and the tunnel oxide layer 30 form a passivated contact structure. The first

electrode 60 and the second electrode 70 may be formed by sintering a metal conductive paste coated on surfaces of the first passivation layer and the second passivation layer. In some embodiments, the first electrode 60 or the second electrode 70 is made of a metal material such as silver, aluminum, copper or nickel.

- 5 **[00150]** Embodiments 1 to 13 and Comparative Examples 1 to 4 of the solar cell manufactured according to the above method are illustrated as below. Parameters are shown in Table 1.

[00151] Table 1 Parameters of the solar cell

| Sample       | Second texture structure                                                    | First texture structure                                                          |                                                                                  | Thickness of the tunnel oxide layer (nm) | Thickness difference between tunnel oxide layers (nm) | First passivation layer          | Thickness of the first passivation layer (nm) | Refractive index of the first passivation layer | Second passivation layer | Thickness of the second passivation layer (nm) | Refractive index of the second passivation layer |
|--------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|------------------------------------------|-------------------------------------------------------|----------------------------------|-----------------------------------------------|-------------------------------------------------|--------------------------|------------------------------------------------|--------------------------------------------------|
|              | Distance between a top and a bottom of a pyramid-shaped microstructure (μm) | Distance between a top surface and a bottom surface of a first substructure (μm) | One-dimensional size of the top surface of the outermost first substructure (μm) |                                          |                                                       |                                  |                                               |                                                 |                          |                                                |                                                  |
| Embodiment 1 | 3.0                                                                         | 1.9                                                                              | 8.6                                                                              | 1.2                                      | 0.12                                                  | Aluminum oxide + silicon nitride | 5+50                                          | 1.92                                            | Silicon nitride          | 70                                             | 1.95                                             |
| Embodiment 2 | 3.2                                                                         | 1.8                                                                              | 8.9                                                                              | 1.2                                      | 0.12                                                  | Aluminum oxide + silicon nitride | 5+60                                          | 1.95                                            | Silicon nitride          | 75                                             | 2.1                                              |
| Embodiment 3 | 3.1                                                                         | 1.7                                                                              | 10.2                                                                             | 1.15                                     | 0.11                                                  | Aluminum oxide + silicon nitride | 5+65                                          | 1.94                                            | Silicon nitride          | 78                                             | 1.9                                              |
| Embodiment 4 | 4.4                                                                         | 1.6                                                                              | 11.6                                                                             | 1.12                                     | 0.11                                                  | Aluminum oxide + silicon nitride | 5+70                                          | 1.93                                            | Silicon nitride          | 80                                             | 2                                                |
| Embodiment 5 | 3.8                                                                         | 1.8                                                                              | 12.4                                                                             | 1.1                                      | 0.11                                                  | Aluminum oxide + silicon nitride | 5+75                                          | 1.95                                            | Silicon nitride          | 82                                             | 2.02                                             |
| Embodiment 6 | 3.6                                                                         | 1.6                                                                              | 13.2                                                                             | 1.1                                      | 0.11                                                  | Aluminum oxide +                 | 5+80                                          | 1.97                                            | Silicon nitride          | 85                                             | 2.03                                             |

|                       |     |     |      |      |      |                                  |        |      |                 |     |             |
|-----------------------|-----|-----|------|------|------|----------------------------------|--------|------|-----------------|-----|-------------|
|                       |     |     |      |      |      | silicon nitride                  |        |      |                 |     |             |
| Embodiment 7          | 3.5 | 1.7 | 14.5 | 1.1  | 0.10 | Aluminum oxide + silicon nitride | 8+85   | 1.98 | Silicon nitride | 88  | 1.98        |
| Embodiment 8          | 3.2 | 1.5 | 12.1 | 1.05 | 0.10 | Aluminum oxide + silicon nitride | 10+100 | 1.95 | Silicon nitride | 90  | 1.96        |
| Embodiment 9          | 3.0 | 1.6 | 15.6 | 1.02 | 0.10 | Silicon nitride                  | 100    | 1.98 | Silicon nitride | 95  | 1.97        |
| Embodiment 10         | 3.0 | 1.5 | 18.2 | 1.0  | 0.10 | Silicon nitride                  | 105    | 1.96 | Silicon nitride | 98  | <b>2.07</b> |
| Embodiment 11         | 2.8 | 1.9 | 24.8 | 0.95 | 0.12 | Silicon nitride                  | 110    | 1.92 | Silicon nitride | 100 | 1.95        |
| Embodiment 12         | 2.7 | 1.4 | 26.3 | 0.95 | 0.08 | Silicon nitride                  | 95     | 2.0  | Silicon nitride | 110 | 1.96        |
| Embodiment 13         | 2.8 | 1.5 | 38.4 | 0.9  | 0.08 | Silicon nitride                  | 90     | 1.95 | Silicon nitride | 120 | 1.97        |
| Comparative Example 1 | 3.0 | 2.5 | 5.5  | 1.3  | 0.18 | Aluminum oxide + silicon nitride | 5+50   | 1.92 | Silicon nitride | 70  | 1.95        |
| Comparative Example 2 | 3.0 | /   | /    | 1.4  | 0.18 | Aluminum oxide + silicon nitride | 5+50   | 1.92 | Silicon nitride | 70  | 1.95        |
| Comparative Example 3 | 3.0 | 1.8 | 8.6  | 1.2  | 0.12 | Aluminum oxide + silicon nitride | 5+50   | 1.92 | Silicon nitride | 70  | 2.15        |
| Comparative Example 4 | 3.0 | 1.8 | 8.6  | 1.2  | 0.12 | Aluminum oxide + silicon nitride | 5      | 1.52 | Silicon nitride | 70  | 1.95        |

\* i.e., thickness difference between a tunnel oxide layer on a top surface of the outermost first substructure and a tunnel oxide layer on a side surface of the of the outermost first substructure

[00152] Table 2 shows parameters used in a deposition process of a tunnel oxide layer and a polycrystalline silicon layer thereon of the solar cell in each embodiment and in each comparative example. In the process, the silicon substrate is installed in a low-pressure chemical vapor deposition (LPCVD) device, the device is vacuumed and the temperature is raised, oxide gas (e.g., oxygen) having a loading temperature is added, and a three-stage oxidation process is conducted, in which a first oxidation period of 1.2 minutes is performed in the first stage, a second oxidation period of 1.3 minutes is performed in the second stage, and a third oxidation period of 1.5 minutes is performed in the third stage, so as to form the tunnel oxide layer on the silicon substrate. Then, the oxide gas is exhausted and nitrogen is added to form an atmosphere in the interior of the device, the temperature of the device is raised to a pre-deposition temperature, a silane gas having a loading temperature is added to the tunnel oxide layer of the silicon substrate for deposition, so as to form the polycrystalline silicon layer.

[00153] Table 2 Deposition parameters of the solar cell

| Sample       | Oxygen source gas loading temperature (°C) | Oxidation temperature 1 (°C) | Oxidation temperature 2 (°C) | Oxidation temperature 3 (°C) | Pre-deposition temperature (°C) | Deposition temperature for the polycrystalline silicon layer (°C) | Silane gas loading temperature (°C) |
|--------------|--------------------------------------------|------------------------------|------------------------------|------------------------------|---------------------------------|-------------------------------------------------------------------|-------------------------------------|
| Embodiment 1 | 590                                        | 590                          | 595                          | 600                          | 620                             | 620                                                               | 590                                 |
| Embodiment 2 | 590                                        | 595                          | 590                          | 600                          | 620                             | 620                                                               | 590                                 |
| Embodiment 3 | 590                                        | 595                          | 600                          | 600                          | 620                             | 620                                                               | 590                                 |
| Embodiment 4 | 590                                        | 590                          | 595                          | 600                          | 625                             | 630                                                               | 590                                 |
| Embodiment 5 | 590                                        | 595                          | 590                          | 600                          | 625                             | 630                                                               | 590                                 |
| Embodiment 6 | 590                                        | 595                          | 600                          | 600                          | 625                             | 630                                                               | 590                                 |

|                       |     |     |     |     |     |     |     |
|-----------------------|-----|-----|-----|-----|-----|-----|-----|
| Embodiment 7          | 600 | 608 | 610 | 600 | 620 | 630 | 600 |
| Embodiment 8          | 600 | 610 | 610 | 610 | 625 | 630 | 600 |
| Embodiment 9          | 600 | 605 | 610 | 600 | 625 | 625 | 600 |
| Embodiment 10         | 610 | 600 | 615 | 600 | 620 | 625 | 610 |
| Embodiment 11         | 615 | 610 | 610 | 610 | 625 | 625 | 615 |
| Embodiment 12         | 615 | 610 | 605 | 600 | 620 | 625 | 615 |
| Embodiment 13         | 615 | 610 | 605 | 600 | 620 | 625 | 615 |
| Comparative Example 1 | 590 | 590 | 590 | 590 | 610 | 610 | 605 |
| Comparative Example 2 | 610 | 610 | 610 | 610 | 620 | 620 | 615 |
| Comparative Example 3 | 630 | 630 | 630 | 630 | 650 | 650 | 645 |
| Comparative Example 4 | 590 | 590 | 590 | 590 | 610 | 610 | 605 |

**[00154]** Table 3 Test results of the solar cell

| Sample                | Open-circuit voltage (mV) | Short-circuit current (A) | Fill factor | Photoelectric conversion efficiency (%) | Contact resistivity (mΩ.cm) |
|-----------------------|---------------------------|---------------------------|-------------|-----------------------------------------|-----------------------------|
| Embodiment 1          | 710                       | 11.06                     | 83.51       | 24.52                                   | 1.26                        |
| Embodiment 2          | 710                       | 11.05                     | 83.04       | 24.36                                   | 1.25                        |
| Embodiment 3          | 710                       | 11.04                     | 83.54       | 24.49                                   | 1.28                        |
| Embodiment 4          | 710                       | 11.11                     | 83.41       | 24.61                                   | 1.27                        |
| Embodiment 5          | 712                       | 11.1                      | 83.43       | 24.66                                   | 1.31                        |
| Embodiment 6          | 712                       | 11.08                     | 83.39       | 24.60                                   | 1.30                        |
| Embodiment 7          | 712                       | 11.09                     | 83.51       | 24.66                                   | 1.29                        |
| Embodiment 8          | 712                       | 11.12                     | 83.04       | 24.59                                   | 1.32                        |
| Embodiment 9          | 688                       | 11.11                     | 83.46       | 23.86                                   | 1.28                        |
| Embodiment 10         | 689                       | 11.1                      | 83.14       | 23.78                                   | 1.27                        |
| Embodiment 11         | 687                       | 11.08                     | 83.27       | 23.70                                   | 1.28                        |
| Embodiment 12         | 688                       | 11.04                     | 83.04       | 23.59                                   | 1.26                        |
| Embodiment 13         | 686                       | 11.05                     | 83.06       | 23.55                                   | 1.29                        |
| Comparative Example 1 | 709                       | 11.03                     | 82.77       | 24.21                                   | 1.53                        |
| Comparative Example 2 | 707                       | 11.04                     | 82.76       | 24.16                                   | 1.51                        |
| Comparative Example 3 | 710                       | 11.04                     | 82.645      | 24.23                                   | 1.54                        |
| Comparative Example 4 | 710                       | 11.04                     | 82.7        | 24.20                                   | 1.50                        |

**[00155]** It can be seen from Embodiment 1 to Embodiment 3 that a distance between the substructures in the first texture structure of the rear surface of the semiconductor substrate is controlled within an ideal range, which can ensure that the roughness of the rear surface of the semiconductor substrate is within an appropriate range, helps to improve the uniformity of the tunnel oxide layer formed on the first texture structure, ensure better performance of the tunnel oxide layer formed, further inhibit a high local doping concentration of the doped conductive layer, reduce contact resistivity, improve the open-circuit voltage of the solar cell, and improve a fill factor and photoelectric conversion efficiency.

**[00156]** In the first texture structure of the solar cell according to Comparative Example 1,

in the direction away from the rear surface and perpendicular to the rear surface, a distance between a top surface of the outermost first substructure and a top surface of the first substructure adjacent thereto is less than or equal to 2  $\mu\text{m}$ . The smaller the one-dimensional size of the top surface of the outermost first substructure, the thicker the tunnel oxide layer formed by deposition. The uniformity of the tunnel oxide layer decreases, resulting in a high local doping concentration of the doped conductive layer formed on the surface of the tunnel oxide layer. The contact resistivity is increased compared with that in Embodiment 1, which leads to the reduction of the open-circuit voltage of the solar cell, as well as the reduction of the fill factor and the photoelectric conversion efficiency.

10 **[00157]** The solar cell according to Comparative Example 2 is not subjected to an alkali-polishing process after texturing, the rear surface has a pyramid-shaped microstructure, and the uniformity of the tunnel oxide layer deposited on the pyramid-shaped microstructure decreases, which easily leads to a high local doping concentration of the doped conductive layer formed on the surface of the tunnel oxide layer. The contact resistivity is increased compared with that in Embodiment 1, which leads to the reduction of the open-circuit voltage of the solar cell, as well as the reduction of the fill factor and the photoelectric conversion efficiency.

15 **[00158]** Although the solar cell according to Comparative Example 3, through the treatment of the substructure of the first texture structure, inhibits a high local doping concentration of the doped conductive layer, the contact resistivity is difficult to further decrease during the metallization due to the use of a silicon nitride layer with a high silicon to nitrogen ratio. Compared with Embodiment 1, the distance between the substructures in the first texture structure of the rear surface of the semiconductor substrate and the refractive index of the second passivation layer are controlled, and a synergistic effect of the two can better reduce the contact resistivity and improve the open-circuit voltage, the fill factor and the photoelectric conversion efficiency of the solar cell.

25 **[00159]** Although the solar cell according to Comparative Example 4, through the treatment of the substructure of the first texture structure, inhibits a high local doping concentration of the doped conductive layer, the contact resistivity increases during the metallization due to the use of an aluminum oxide layer and a silicon nitride layer with a lower overall refractive index as the first passivation layer.

30

**[00160]** The present disclosure has been disclosed as above with preferred embodiments, the present disclosure should not be limited by those embodiments. Any person skilled in the art may make several possible changes and modifications without departing from the conception of the present disclosure. Therefore, the protection scope of the present disclosure should be  
5 subject to the scope defined by the claims of the present disclosure.

## CLAIMS

What is claimed is:

1. A solar cell, comprising:

5 a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure has a non-pyramid-shaped microstructure and includes two or more first substructures at least partially stacked on one another, a top surface of the first substructure is a polygonal plane, and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ; and wherein a front surface of the semiconductor substrate has a second texture structure, the second texture structure includes  
10 a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ ;

15 a first passivation layer located on the second texture structure of the front surface of the semiconductor substrate;

a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;

a doped conductive layer located on a surface of the tunnel oxide layer; and

20 a second passivation layer located on a surface of the doped conductive layer.

2. The solar cell according to claim 1, wherein for the two or more first substructures at least partially stacked on one another, in the direction away from the rear surface and perpendicular to the rear surface, a distance between the top surface of the outermost first substructure and the top surface of the adjacent first substructure is equal to or less than 2 $\mu\text{m}$ .

25 3. The solar cell according to claim 1, wherein a shape of the polygonal plane includes at least one of a diamond, a square, a trapezoid, a substantially diamond, a substantially square or a substantially trapezoid.

4. The solar cell according to claim 1, wherein a thickness of the tunnel oxide layer on the

top surface of the outermost first substructure is less than a thickness of the tunnel oxide layer on a side surface of the outermost first substructure.

5        5. The solar cell according to claim 1, wherein the first texture structure further includes two or more adjacent second substructures that do not stacked on one another, and a one-dimensional size of a top surface of the second substructure away from the rear surface is less than or equal to 45  $\mu\text{m}$ .

6. The solar cell according to claim 5, wherein the top surface of the second substructure is a polygonal plane.

10       7. The solar cell according to claim 1, wherein the tunnel oxide layer includes at least one of a silicon oxide layer, an aluminum oxide layer, a silicon oxynitride layer, a molybdenum oxide layer or a hafnium oxide layer.

8. The solar cell according to claim 7, wherein the tunnel oxide layer has a thickness ranging from 0.8 nm to 2 nm.

15       9. The solar cell according to claim 1, wherein the second passivation layer includes at least one of a silicon nitride layer, a silicon oxide layer or a silicon oxynitride layer.

10       10 The solar cell according to claim 9, wherein the second passivation layer has a thickness ranging from 70 nm to 120 nm.

20       11. The solar cell according to claim 1, wherein the first passivation layer includes at least one of a silicon oxide layer, a silicon nitride layer, an aluminum oxide layer or a silicon oxynitride layer.

12. The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer and a silicon nitride layer.

13. The solar cell according to claim 12, wherein the silicon nitride layer has a thickness ranging from 50 nm to 110 nm.

25       14. The solar cell according to claim 1, wherein the first passivation layer is a stacked passivation structure of an aluminum oxide layer, a silicon nitride layer and a silicon oxynitride layer sequentially stacked.

15. The solar cell according to claim 12, wherein the aluminum oxide layer has a thickness ranging from 2 nm to 10 nm.

30       16. The solar cell according to claim 14, wherein the silicon nitride layer has a thickness

ranging from 40 nm to 80 nm.

17. The solar cell according to claim 14, wherein the silicon oxynitride layer has a thickness ranging from 10 nm to 60 nm.

18. The solar cell according to claim 1, wherein the semiconductor substrate is an N-type monocrystalline silicon substrate, the doped conductive layer is an N-type doped polycrystalline silicon layer, an N-type doped microcrystalline silicon layer or an N-type doped amorphous silicon layer.

19. The solar cell according to claim 18, wherein the doped conductive layer has a thickness ranging from 60 nm to 200 nm.

20. A photovoltaic module, comprising a plurality of solar cell strings, wherein each of the plurality of solar cell strings comprises solar cells, and at least one of the solar cells comprises:

a semiconductor substrate, wherein a rear surface of the semiconductor substrate has a first texture structure, the first texture structure has a non-pyramid-shaped microstructure and includes two or more first substructures at least partially stacked on one another, a top surface of the first substructure is a polygonal plane, and a one-dimensional size of the top surface of the outermost first substructure is less than or equal to 45  $\mu\text{m}$ ; and wherein a front surface of the semiconductor substrate has a second texture structure, the second texture structure includes a pyramid-shaped microstructure, the pyramid-shaped microstructure includes a top portion away from the front surface of the semiconductor substrate and a bottom portion close to the front surface of the semiconductor substrate, and in a direction away from the front surface and perpendicular to the front surface, a distance between the top portion and the bottom portion of the pyramid-shaped microstructure is less than or equal to 5  $\mu\text{m}$ ;

a first passivation layer located on the second texture structure of the front surface of the semiconductor substrate;

a tunnel oxide layer located on the first texture structure of the rear surface of the semiconductor substrate;

a doped conductive layer located on a surface of the tunnel oxide layer; and

a second passivation layer located on a surface of the doped conductive layer.

## ABSTRACT

Provided are a solar cell, a manufacturing method thereof, and a photovoltaic module. The solar cell includes: a semiconductor substrate, in which a rear surface of the semiconductor substrate having a first texture structure, the first texture structure includes two or more first substructures at least partially stacked on one another, and in a direction away from the rear surface and perpendicular to the rear surface, a distance between a top surface of an outermost first substructure and a top surface of an adjacent first substructure being less than or equal to 2  $\mu\text{m}$ ; a first passivation layer located on a front surface of the semiconductor substrate; a tunnel oxide layer located on the first texture structure; a doped conductive layer located on a surface of the tunnel oxide layer; and a second passivation layer located on a surface of the doped conductive layer.

(Fig. 1)

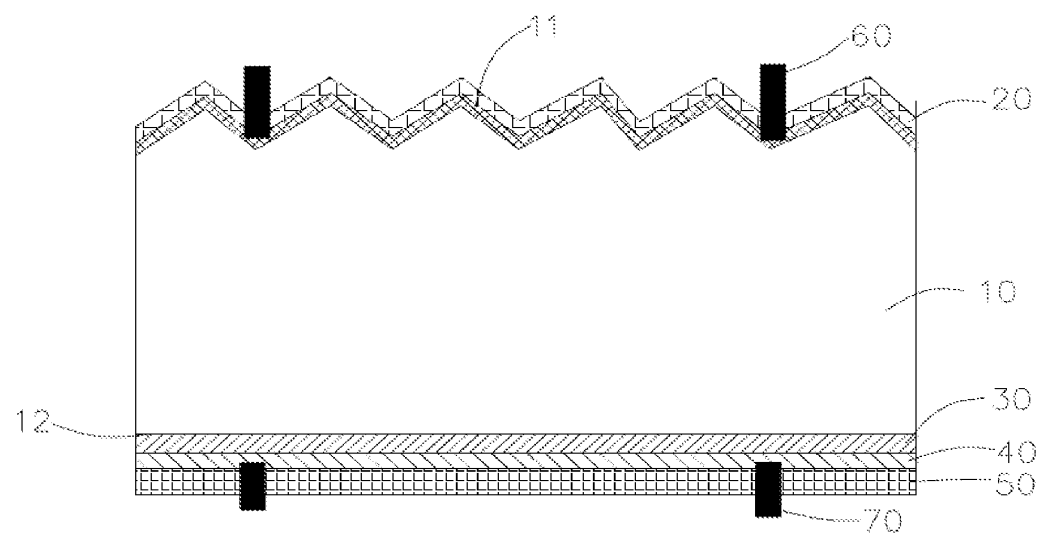


FIG. 1

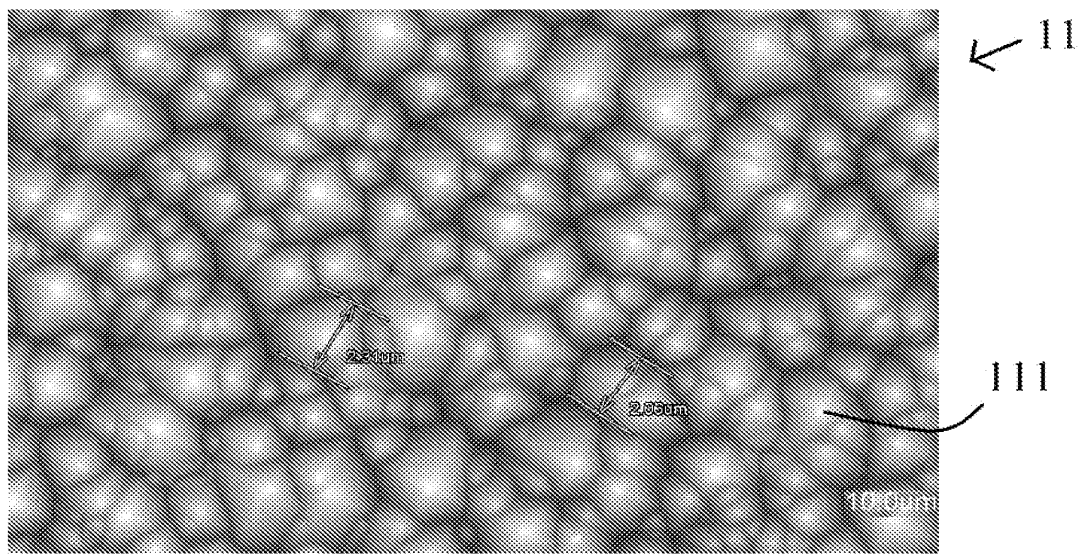


FIG. 2

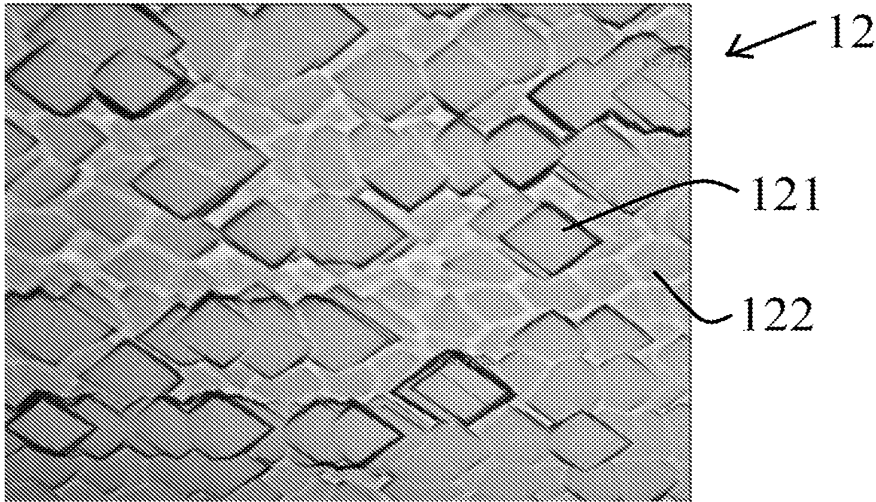


FIG. 3

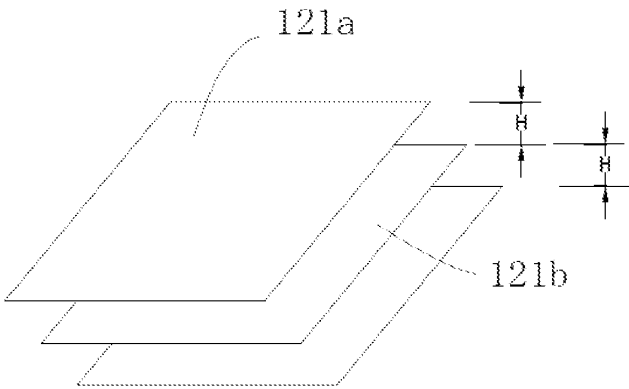


FIG. 4a

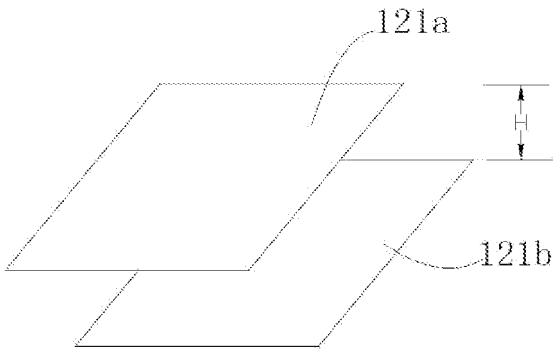


FIG. 4b

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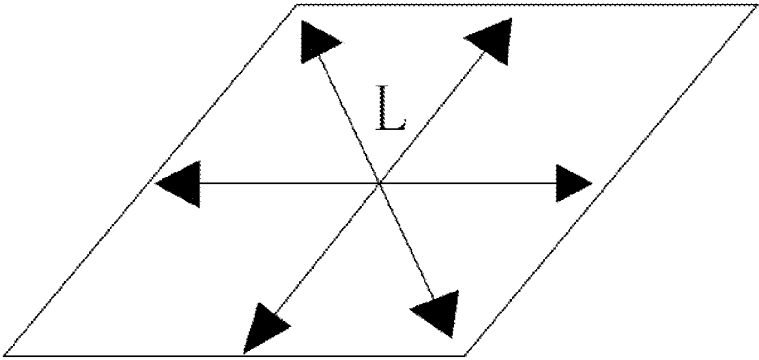


FIG. 5

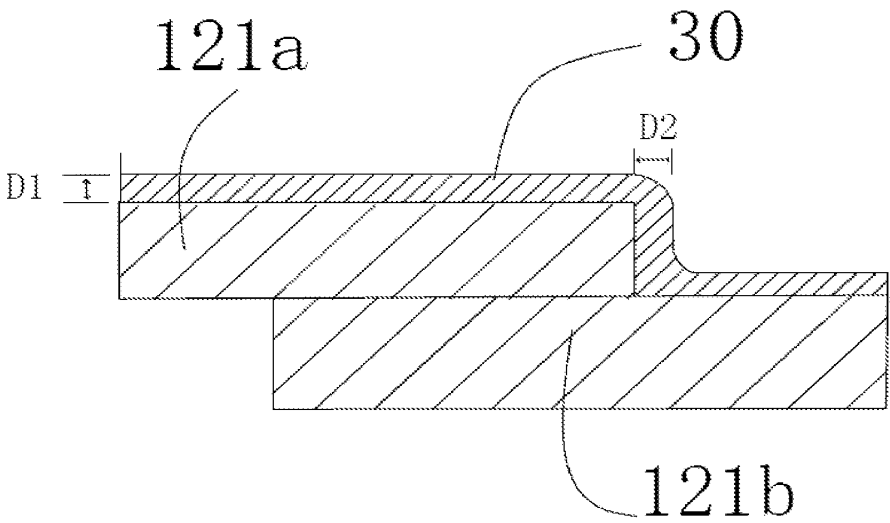


FIG. 6

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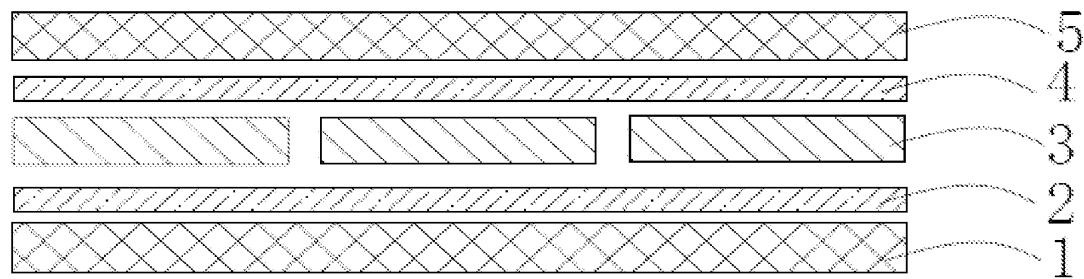


FIG. 7a

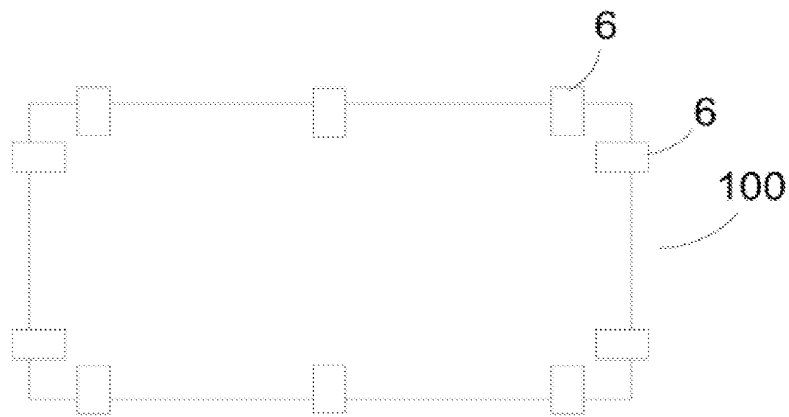


FIG. 7b

5/5

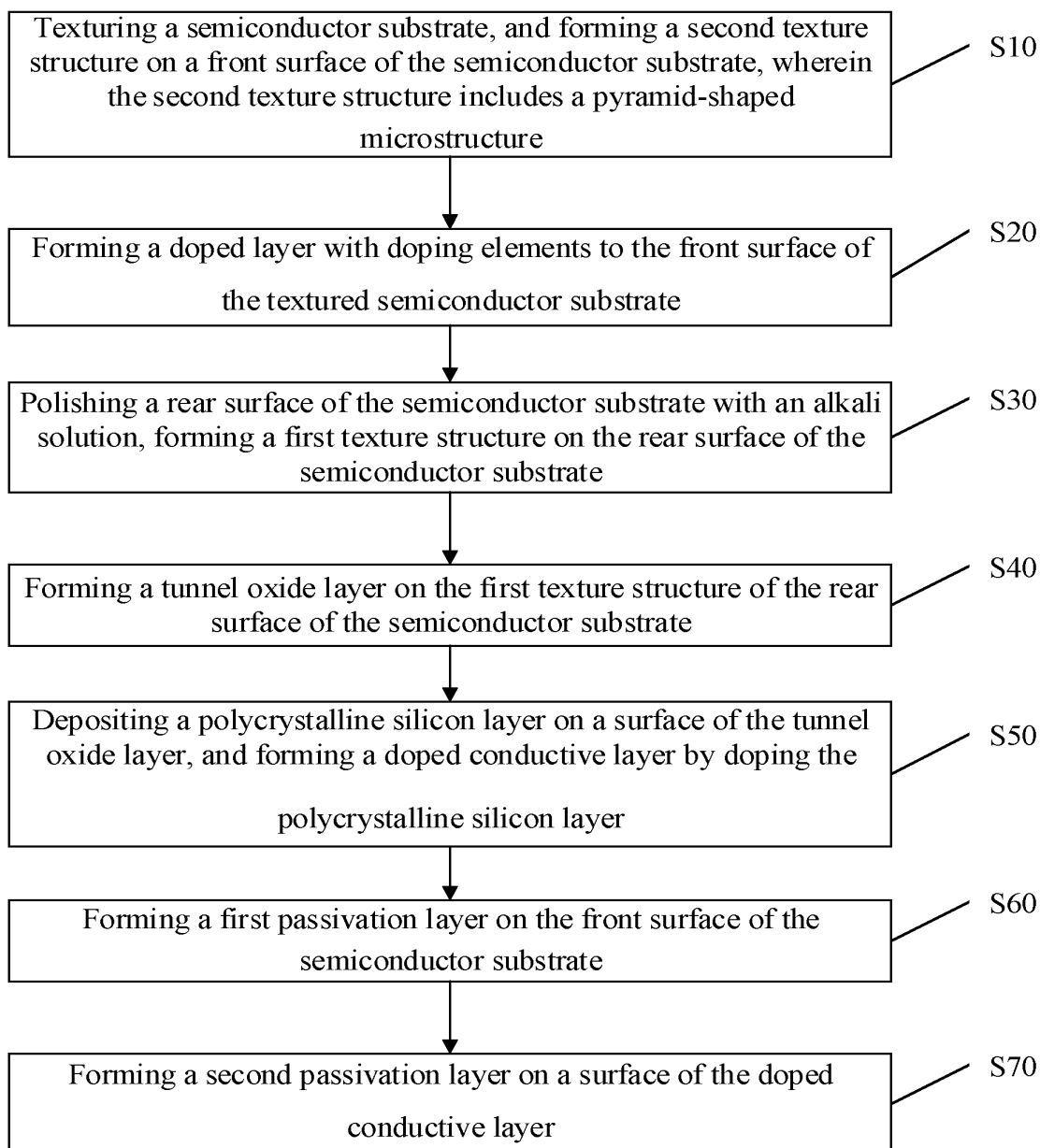


FIG. 8

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)**

Title of  
Invention

**SOLAR CELL, MANUFACTURING METHOD THEREOF, AND  
PHOTOVOLTAIC MODULE**

As the below named inventor, I hereby declare that:

This declaration  
is directed to:



The attached application, or



United States application or PCT international application number \_\_\_\_\_

filed on \_\_\_\_\_

The above-identified application was made or authorized to be made by me

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

**WARNING:**

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LEGAL NAME OF INVENTOR

Inventor: LIU, Changming

Date (Optional):

2021.8.7

Signature

LIU, Changming

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.83. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1480, Alexandria, VA 22313-1480. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1480, Alexandria, VA 22313-1480.

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APPLICATION DATA SHEET (37 CFR 1.76)**

|                               |                                                                              |
|-------------------------------|------------------------------------------------------------------------------|
| <b>Title of<br/>Invention</b> | <b>SOLAR CELL, MANUFACTURING METHOD THEREOF, AND<br/>PHOTOVOLTAIC MODULE</b> |
|-------------------------------|------------------------------------------------------------------------------|

As the below named inventor, I hereby declare that:

This declaration  
is directed to:



The attached application, or



United States application or PCT International application number \_\_\_\_\_  
filed on \_\_\_\_\_

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001  
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**LEGAL NAME OF INVENTOR**

Inventor: YU, Kun

Date (Optional): 2021. 8.17

Signature: YU, Kun

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.83. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Title of Invention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE</b> |
| As the below named inventor, I hereby declare that:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                          |
| This declaration is directed to: <input checked="" type="checkbox"/> The attached application, or                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                          |
| <input type="checkbox"/> United States application or PCT international application number _____<br>filed on _____                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                          |
| The above-identified application was made or authorized to be made by me.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                          |
| I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                          |
| I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                          |
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| LEGAL NAME OF INVENTOR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                          |
| Inventor: <u>ZHANG, Xinyu</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Date (Optional) <u>2021-8-17</u>                                         |
| Signature: <u>ZHANG, Xinyu</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                          |
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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------|-------------------|
| <b>Application Data Sheet 37 CFR 1.76</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                   | <b>Attorney Docket Number</b> | 084546-000044USD1 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                   | <b>Application Number</b>     |                   |
| <b>Title of Invention</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                               |                   |
| <p>The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.</p> <p>This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.</p> |                                                                   |                               |                   |

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☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

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|                                                                                                                                                                                 |                                     |                                         |                    |               |               |
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| <b>Legal Name</b>                                                                                                                                                               |                                     |                                         |                    |               |               |
| <b>Prefix</b>                                                                                                                                                                   | <b>Given Name</b>                   | <b>Middle Name</b>                      | <b>Family Name</b> | <b>Suffix</b> |               |
|                                                                                                                                                                                 | Kun                                 |                                         | YU                 |               |               |
| <b>Residence Information (Select One)</b> <input type="radio"/> US Residency <input checked="" type="radio"/> Non US Residency <input type="radio"/> Active US Military Service |                                     |                                         |                    |               |               |
| <b>City</b>                                                                                                                                                                     | Haining, Zhejiang                   | <b>Country of Residence<sup>i</sup></b> | CN                 |               |               |
| <b>Mailing Address of Inventor:</b>                                                                                                                                             |                                     |                                         |                    |               |               |
| <b>Address 1</b>                                                                                                                                                                | No. 58, Yuan Xi Road, Yuan Hua Town |                                         |                    |               |               |
| <b>Address 2</b>                                                                                                                                                                |                                     |                                         |                    |               |               |
| <b>City</b>                                                                                                                                                                     | Haining, Zhejiang                   | <b>State/Province</b>                   |                    |               |               |
| <b>Postal Code</b>                                                                                                                                                              |                                     | <b>Country<sup>i</sup></b>              | CN                 |               |               |
| <b>Inventor 2</b>                                                                                                                                                               |                                     |                                         |                    |               | <b>Remove</b> |
| <b>Legal Name</b>                                                                                                                                                               |                                     |                                         |                    |               |               |
| <b>Prefix</b>                                                                                                                                                                   | <b>Given Name</b>                   | <b>Middle Name</b>                      | <b>Family Name</b> | <b>Suffix</b> |               |
|                                                                                                                                                                                 | Changming                           |                                         | LIU                |               |               |
| <b>Residence Information (Select One)</b> <input type="radio"/> US Residency <input checked="" type="radio"/> Non US Residency <input type="radio"/> Active US Military Service |                                     |                                         |                    |               |               |
| <b>City</b>                                                                                                                                                                     | Haining, Zhejiang                   | <b>Country of Residence<sup>i</sup></b> | CN                 |               |               |
| <b>Mailing Address of Inventor:</b>                                                                                                                                             |                                     |                                         |                    |               |               |
| <b>Address 1</b>                                                                                                                                                                | No. 58, Yuan Xi Road, Yuan Hua Town |                                         |                    |               |               |
| <b>Address 2</b>                                                                                                                                                                |                                     |                                         |                    |               |               |
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| <b>Inventor 3</b>                                                                                                                                                               |                                     |                                         |                    |               | <b>Remove</b> |
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| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | 084546-000044USD1 |
|                                           |                                                                   | Application Number     |                   |
| Title of Invention                        | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                        |                   |

|                                                                                                                                                                             |                   |                                     |                                   |        |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------------|-----------------------------------|--------|
| Prefix                                                                                                                                                                      | Given Name        | Middle Name                         | Family Name                       | Suffix |
|                                                                                                                                                                             | Xinyu             |                                     | ZHANG                             |        |
| Residence Information (Select One) <input type="radio"/> US Residency <input checked="" type="radio"/> Non US Residency <input type="radio"/> Active US Military Service    |                   |                                     |                                   |        |
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| Mailing Address of Inventor:                                                                                                                                                |                   |                                     |                                   |        |
| Address 1                                                                                                                                                                   |                   | No. 58, Yuan Xi Road, Yuan Hua Town |                                   |        |
| Address 2                                                                                                                                                                   |                   |                                     |                                   |        |
| City                                                                                                                                                                        | Haining, Zhejiang |                                     | State/Province                    |        |
| Postal Code                                                                                                                                                                 |                   | Country <sup>i</sup>                | CN                                |        |
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|                                         |                                                                   |                                           |                          |
|-----------------------------------------|-------------------------------------------------------------------|-------------------------------------------|--------------------------|
| Title of the Invention                  | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                                           |                          |
| Attorney Docket Number                  | 084546-000044USD1                                                 | Small Entity Status Claimed               | <input type="checkbox"/> |
| Application Type                        | Nonprovisional                                                    |                                           |                          |
| Subject Matter                          | Utility                                                           |                                           |                          |
| Total Number of Drawing Sheets (if any) |                                                                   | Suggested Figure for Publication (if any) |                          |

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Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

|                                                        |                          |                                                         |
|--------------------------------------------------------|--------------------------|---------------------------------------------------------|
| Application number of the previously filed application | Filing date (YYYY-MM-DD) | Intellectual Property Authority or Country <sup>i</sup> |
|                                                        |                          |                                                         |

|                                           |                                                                   |                        |                   |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|-------------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | 084546-000044USD1 |
|                                           |                                                                   | Application Number     |                   |
| Title of Invention                        | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                        |                   |

**Publication Information:**

|                          |                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> | Request Early Publication (Fee required at time of Request 37 CFR 1.219)                                                                                                                                                                                                                                                                                                                      |
| <input type="checkbox"/> | <b>Request Not to Publish.</b> I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application <b>has not and will not</b> be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing. |

**Representative Information:**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                  |                                              |                                                         |                    |                                                  |                                              |                                                         |                 |       |  |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|----------------------------------------------|---------------------------------------------------------|--------------------|--------------------------------------------------|----------------------------------------------|---------------------------------------------------------|-----------------|-------|--|--|
| Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing. |                                                  |                                              |                                                         |                    |                                                  |                                              |                                                         |                 |       |  |  |
| <table border="1"> <tr> <td>Please Select One:</td> <td><input checked="" type="radio"/> Customer Number</td> <td><input type="radio"/> US Patent Practitioner</td> <td><input type="radio"/> Limited Recognition (37 CFR 11.9)</td> </tr> <tr> <td>Customer Number</td> <td colspan="3">22204</td> </tr> </table>                                                                                                                                              |                                                  |                                              |                                                         | Please Select One: | <input checked="" type="radio"/> Customer Number | <input type="radio"/> US Patent Practitioner | <input type="radio"/> Limited Recognition (37 CFR 11.9) | Customer Number | 22204 |  |  |
| Please Select One:                                                                                                                                                                                                                                                                                                                                                                                                                                              | <input checked="" type="radio"/> Customer Number | <input type="radio"/> US Patent Practitioner | <input type="radio"/> Limited Recognition (37 CFR 11.9) |                    |                                                  |                                              |                                                         |                 |       |  |  |
| Customer Number                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 22204                                            |                                              |                                                         |                    |                                                  |                                              |                                                         |                 |       |  |  |

**Domestic Benefit/National Stage Information:**

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

|                                                                                                                       |                 |                          |                                    |
|-----------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------|------------------------------------|
| Prior Application Status                                                                                              | Pending         | <a href="#">Remove</a>   |                                    |
| Application Number                                                                                                    | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
|                                                                                                                       | Division of     | 17459689                 | 2021-08-27                         |
| Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the <b>Add</b> button. |                 |                          |                                    |

**Foreign Priority Information:**

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)<sup>i</sup> the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

|                    |                      |                          |                                          |
|--------------------|----------------------|--------------------------|------------------------------------------|
| Application Number | Country <sup>i</sup> | Filing Date (YYYY-MM-DD) | <a href="#">Remove</a>                   |
|                    |                      |                          | Access Code <sup>i</sup> (if applicable) |

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                                                                                        |                                                                   |                        |                   |
|--------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|------------------------|-------------------|
| <b>Application Data Sheet 37 CFR 1.76</b>                                                              |                                                                   | Attorney Docket Number | 084546-000044USD1 |
|                                                                                                        |                                                                   | Application Number     |                   |
| Title of Invention                                                                                     | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                        |                   |
| 202110895225.8                                                                                         | CN                                                                | 2021-08-04             | 5E05              |
| Additional Foreign Priority Data may be generated within this form by selecting the <b>Add</b> button. |                                                                   |                        |                   |

## Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.</p> <p><input type="checkbox"/> NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.</p> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                           |                                                                   |                        |                   |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|-------------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | 084546-000044USD1 |
|                                           |                                                                   | Application Number     |                   |
| Title of Invention                        | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                        |                   |

## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE:** This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

### 1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

### 2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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|                                           |                                                                   |                        |                   |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|-------------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | 084546-000044USD1 |
|                                           |                                                                   | Application Number     |                   |
| Title of Invention                        | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                        |                   |

## Applicant Information:

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                                                                        |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------------------|--|
| Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                             |                                                                        |  |
| <b>Applicant 1</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                                                                        |  |
| <p>If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.</p> |                                                             |                                                                        |  |
| <input type="button" value="Clear"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             |                                                                        |  |
| <input checked="" type="radio"/> Assignee                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             | <input type="radio"/> Legal Representative under 35 U.S.C. 117         |  |
| <input type="radio"/> Person to whom the inventor is obligated to assign.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             | <input type="radio"/> Person who shows sufficient proprietary interest |  |
| If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                                                                        |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                                                                        |  |
| Name of the Deceased or Legally Incapacitated Inventor: <input type="text"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                             |                                                                        |  |
| If the Applicant is an Organization check here. <input checked="" type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                             |                                                                        |  |
| Organization Name                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | SHANGHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD. |                                                                        |  |
| <b>Mailing Address Information For Applicant:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                                                                        |  |
| Address 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 5/F, No. 277 Huqingping Road                                |                                                                        |  |
| Address 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                                                                        |  |
| City                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Minhang District, Shanaghai                                 | State/Province                                                         |  |
| Country                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | CN                                                          | Postal Code                                                            |  |
| Phone Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                             | Fax Number                                                             |  |
| Email Address                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                             |                                                                        |  |
| Additional Applicant Data may be generated within this form by selecting the Add button.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                             |                                                                        |  |

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|-------------------------------------------|-------------------------------------------------------------------|-------------------|
| <b>Application Data Sheet 37 CFR 1.76</b> | Attorney Docket Number                                            | 084546-000044USD1 |
|                                           | Application Number                                                |                   |
| Title of Invention                        | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                   |

**Applicant 2**

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

- ☒ Assignee ☐ Legal Representative under 35 U.S.C. 117 ☐ Joint Inventor
- ☐ Person to whom the inventor is obligated to assign. ☐ Person who shows sufficient proprietary interest

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name ZHEJIANG JINKO SOLAR CO., LTD.

**Mailing Address Information For Applicant:**

Address 1 No. 58, Yuan Xi Road, Yuan Hua Town

Address 2

City Haining, Zhejiang

State/Province

Country CN

Postal Code

Phone Number

Fax Number

Email Address

Additional Applicant Data may be generated within this form by selecting the Add button.

**Assignee Information including Non-Applicant Assignee Information:**

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

**Assignee 1**

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                           |                                                                   |                        |                   |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|-------------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | 084546-000044USD1 |
|                                           |                                                                   | Application Number     |                   |
| Title of Invention                        | SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE |                        |                   |

|        |            |             |             |        |
|--------|------------|-------------|-------------|--------|
| Prefix | Given Name | Middle Name | Family Name | Suffix |
|        |            |             |             |        |

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

|                      |  |                |  |
|----------------------|--|----------------|--|
| Address 1            |  |                |  |
| Address 2            |  |                |  |
| City                 |  | State/Province |  |
| Country <sup>i</sup> |  | Postal Code    |  |
| Phone Number         |  | Fax Number     |  |
| Email Address        |  |                |  |

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

**Signature:**

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is **not** checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

|            |                                    |           |                   |                     |        |
|------------|------------------------------------|-----------|-------------------|---------------------|--------|
| Signature  | /Jeffrey L. Costellia, Reg.#35483/ |           | Date (YYYY-MM-DD) | 2022-10-12          |        |
| First Name | Jeffrey L.                         | Last Name | Costellia         | Registration Number | 35,483 |

Additional Signature may be generated within this form by selecting the Add button.

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

## Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

- 1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
- 2 A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
- 3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
- 4 A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
- 5 A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
- 6 A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
- 7 A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
- 8 A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
- 9 A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Under the Paperwork Reduction Act of 1995, no person is required to respond to a collection of information unless it displays a valid OMB control number

## POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

☒ Practitioners associated with Customer Number: 22204

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

| Name | Registration Number |
|------|---------------------|
|      |                     |
|      |                     |
|      |                     |
|      |                     |
|      |                     |

| Name | Registration Number |
|------|---------------------|
|      |                     |
|      |                     |
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|      |                     |
|      |                     |

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

☒ The address associated with Customer Number: 22204

OR

|                                                  |       |       |
|--------------------------------------------------|-------|-------|
| <input type="checkbox"/> Firm or individual name |       |       |
| Address                                          |       |       |
| City                                             | State | Zip   |
| Country                                          |       |       |
| Telephone                                        |       | Email |

Assignee name and address: SHANGHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD.  
5/F, No. 277 Huqingping Road, Minhang District, Shanghai, China

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of the practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

### SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

Signature Shaofa LAN Date 2021-09-02

Name Shaofa LAN Telephone

Title Intellectual Property Director

This collection of information is required by 37 CFR 1.31, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public, which is to update (and by the USPTO to process) the file of a patent or reexamination proceeding. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 18 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DC NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.  
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Under the Paperwork Reduction Act of 1995, no person is required to respond to a collection of information unless it displays a valid OMB control number.

**POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO**

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:



Practitioners associated with Customer Number:

22204

**OR**

Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

| Name | Registration Number |
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|      |                     |

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:



The address associated with Customer Number:

22204

**OR**

Firm or individual name

Address

City

State

Zip

Country

Telephone

Email

Assignee name and address: ZHEJIANG JINKO SOLAR CO., LTD.  
No. 58, Yuan Xi Road, Yuan Hua Town, Haining,  
Zhejiang, China

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of the practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

**SIGNATURE of Assignee of Record**

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

Signature

Shaofa LAN

Date 2021-09-02

Name Shaofa LAN

Telephone

Title Intellectual Property Director

This collection of information is required by 37 CFR 1.31, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public, which is to update (and by the USPTO to process) the file of a patent or reexamination proceeding. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 19 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

**STATEMENT UNDER 37 CFR 3.73(c)**

Applicant/Patent Owner: (1.) SHANGHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD. (2.) ZHEJIANG JINKO SOLAR CO., LTD.

Application No./Patent No.: \_\_\_\_\_ Filed/Issue Date: **October 12, 2022**Titled: **SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE**

(1.) SHANGHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD. (2.) ZHEJIANG JINKO SOLAR

, a **corporation**

(Name of Assignee)

(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):1. ☒ The assignee of the entire right, title, and interest.2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):☐ The extent (by percentage) of its ownership interest is \_\_\_\_%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.4. ☐ The recipient, via a court proceeding or the like (e.g., bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):A. ☒ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 057314, Frame 0980, or for which a copy thereof is attached.B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: \_\_\_\_\_ To: \_\_\_\_\_

The document was recorded in the United States Patent and Trademark Office at

Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

2. From: \_\_\_\_\_ To: \_\_\_\_\_

The document was recorded in the United States Patent and Trademark Office at

Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

[Page 1 of 2]

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

**STATEMENT UNDER 37 CFR 3.73(c)**

3. From: \_\_\_\_\_ To: \_\_\_\_\_

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Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

4. From: \_\_\_\_\_ To: \_\_\_\_\_

The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

5. From: \_\_\_\_\_ To: \_\_\_\_\_

The document was recorded in the United States Patent and Trademark Office at  
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6. From: \_\_\_\_\_ To: \_\_\_\_\_

The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☒ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Jeffrey L. Costellia, #35483/

October 12, 2022

Signature

Date

Jeffrey L. Costellia, Attorney of Record

35,483

Printed or Typed Name

Title or Registration Number

## Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

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3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.



**UNITED STATES PATENT AND TRADEMARK OFFICE**

UNDER SECRETARY OF COMMERCE FOR INTELLECTUAL PROPERTY AND  
DIRECTOR OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

AUGUST 30, 2021

PTAS

NIXON PEABODY LLP  
799 9TH STREET NW  
SUITE 500  
WASHINGTON, DC 20001

**506841821**

UNITED STATES PATENT AND TRADEMARK OFFICE  
NOTICE OF RECORDATION OF ASSIGNMENT DOCUMENT

THE ENCLOSED DOCUMENT HAS BEEN RECORDED BY THE ASSIGNMENT RECORDATION BRANCH OF THE U.S. PATENT AND TRADEMARK OFFICE. A COMPLETE COPY IS AVAILABLE AT THE ASSIGNMENT SEARCH ROOM ON THE REEL AND FRAME NUMBER REFERENCED BELOW.

PLEASE REVIEW ALL INFORMATION CONTAINED ON THIS NOTICE. THE INFORMATION CONTAINED ON THIS RECORDATION NOTICE REFLECTS THE DATA PRESENT IN THE PATENT AND TRADEMARK ASSIGNMENT SYSTEM. IF YOU SHOULD FIND ANY ERRORS OR HAVE QUESTIONS CONCERNING THIS NOTICE, YOU MAY CONTACT THE ASSIGNMENT RECORDATION BRANCH AT 571-272-3350. PLEASE SEND REQUEST FOR CORRECTION TO: U.S. PATENT AND TRADEMARK OFFICE, MAIL STOP: ASSIGNMENT RECORDATION BRANCH, P.O. BOX 1450, ALEXANDRIA, VA 22313.

RECORDATION DATE: 08/27/2021

REEL/FRAME: 057314/0980  
NUMBER OF PAGES: 4

BRIEF: ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS).

DOCKET NUMBER: 084546-000033

ASSIGNOR:  
YU, KUN

DOC DATE: 08/17/2021

ASSIGNOR:  
LIU, CHANGMING

DOC DATE: 08/17/2021

ASSIGNOR:  
ZHANG, XINYU

DOC DATE: 08/17/2021

ASSIGNEE:  
SHANGHAI JINKO GREEN ENERGY  
ENTERPRISE MANAGEMENT CO., LTD.  
5/F, NO. 277 HUQINGPING ROAD  
MINHANG DISTRICT, SHANGHAI, CHINA

ASSIGNEE:  
ZHEJIANG JINKO SOLAR CO., LTD.  
58, YUANG XI ROAD, YUAN HUA TOWN  
HAINING, ZHEJIANG, CHINA

|                                                                             |              |
|-----------------------------------------------------------------------------|--------------|
| APPLICATION NUMBER: 17459689                                                | FILING DATE: |
| PATENT NUMBER:                                                              | ISSUE DATE:  |
| TITLE: SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC<br>MODULE |              |

ASSIGNMENT RECORDATION BRANCH  
PUBLIC RECORDS DIVISION

## PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1  
 Stylesheet Version v1.2

EPAS ID: PAT6888642

|                                                                                                                                                                                                 |                                                             |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| <b>SUBMISSION TYPE:</b>                                                                                                                                                                         | NEW ASSIGNMENT                                              |
| <b>NATURE OF CONVEYANCE:</b>                                                                                                                                                                    | ASSIGNMENT                                                  |
| <b>CONVEYING PARTY DATA</b>                                                                                                                                                                     |                                                             |
| <b>Name</b>                                                                                                                                                                                     | <b>Execution Date</b>                                       |
| KUN YU                                                                                                                                                                                          | 08/17/2021                                                  |
| CHANGMING LIU                                                                                                                                                                                   | 08/17/2021                                                  |
| XINYU ZHANG                                                                                                                                                                                     | 08/17/2021                                                  |
| <b>RECEIVING PARTY DATA</b>                                                                                                                                                                     |                                                             |
| <b>Name:</b>                                                                                                                                                                                    | SHANGHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD. |
| <b>Street Address:</b>                                                                                                                                                                          | 5/F, NO. 277 HUQINGPING ROAD                                |
| <b>City:</b>                                                                                                                                                                                    | MINHANG DISTRICT, SHANGHAI                                  |
| <b>State/Country:</b>                                                                                                                                                                           | CHINA                                                       |
| <b>Name:</b>                                                                                                                                                                                    | ZHEJIANG JINKO SOLAR CO., LTD.                              |
| <b>Street Address:</b>                                                                                                                                                                          | 58, YUANG XI ROAD, YUAN HUA TOWN                            |
| <b>City:</b>                                                                                                                                                                                    | HAINING, ZHEJIANG                                           |
| <b>State/Country:</b>                                                                                                                                                                           | CHINA                                                       |
| <b>PROPERTY NUMBERS Total: 1</b>                                                                                                                                                                |                                                             |
| <b>Property Type</b>                                                                                                                                                                            | <b>Number</b>                                               |
| <b>Application Number:</b>                                                                                                                                                                      | 17459689                                                    |
| <b>CORRESPONDENCE DATA</b>                                                                                                                                                                      |                                                             |
| <b>Fax Number:</b>                                                                                                                                                                              | (202)585-8080                                               |
| <i>Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.</i> |                                                             |
| <b>Phone:</b>                                                                                                                                                                                   | 202-585-8000                                                |
| <b>Email:</b>                                                                                                                                                                                   | nnpatent@nixonpeabody.com, dsias@nixonpeabody.com           |
| <b>Correspondent Name:</b>                                                                                                                                                                      | NIXON PEABODY LLP                                           |
| <b>Address Line 1:</b>                                                                                                                                                                          | 799 9TH STREET NW                                           |
| <b>Address Line 2:</b>                                                                                                                                                                          | SUITE 500                                                   |
| <b>Address Line 4:</b>                                                                                                                                                                          | WASHINGTON, D.C. 20001                                      |
| <b>ATTORNEY DOCKET NUMBER:</b>                                                                                                                                                                  | 084546-000033                                               |
| <b>NAME OF SUBMITTER:</b>                                                                                                                                                                       | JEFFREY L. COSTELLIA                                        |
| <b>SIGNATURE:</b>                                                                                                                                                                               | /Jeffery L. Costellia, Reg. No. 35,483/                     |
| <b>DATE SIGNED:</b>                                                                                                                                                                             | 08/27/2021                                                  |

# ASSIGNMENT

WHEREAS, we, YU, Kun of China, Zhejiang Province, LIU, Changming of China, Zhejiang Province, ZHANG, Xinyu of China, Zhejiang Province ("Assignor"), are the inventors of an invention entitled "SOLAR CELL, MANUFACTURING METHOD THEREOF, AND PHOTOVOLTAIC MODULE" that is the subject matter of: (check all that apply)

- ☒ a U.S. application for Letters Patent which claims the priority of the Chinese Patent Application No. 202110895225.8 filed on August 4, 2021;
- ☐ an application made under the Patent Cooperation Treaty which is identifiable at WIPO by Application No. PCT/\_\_\_ filed on \_\_\_;
- ☐ an application for Letters Patent which is identifiable in the Patent Office of \_\_\_ the U.S. by Application No. \_\_\_\_\_ filed on \_\_\_\_\_;

WHEREAS, SHANGHAI JINKO GREEN ENERGY ENTERPRISE MANAGEMENT CO., LTD. located 5/F, No.277 Huggingping Road, Minhang District, Shanghai, China and ZHEJIANG JINKO SOLAR CO., LTD. located NO. 58, YUAN XI ROAD, YUAN HUA TOWN, HAINING, ZHEJIANG, CHINA hereinafter referred to as "Assignee", are desirous of acquiring the entire right, title and interest in and to the invention, the applications, and any and all Letters Patent or similar foreign or domestic legal protection;

- ☒ in the United States
- ☐ in all other countries or jurisdictions;

"NOW THEREFORE, for good and valuable consideration, the receipt and adequacy of which is hereby acknowledged,

- a) we agree to transfer, and
- b) we do hereby transfer,

to Assignee, its successors and assigns, effective as of August 4, 2021 *nunc pro tunc*, our entire right, title and interest in the above named countries and jurisdictions in and to the following including the right to sue for past infringement: the invention, the above-identified applications, all applications from which any of the above-identified applications claim priority, corresponding U.S. and non-U.S. applications, any continuation, division, renewal, or substitute for the applications, all Letters Patent, any reissue, re-examination, or similar legal protection issuing related to the Letters Patent, and all rights and benefits under any applicable treaty or convention, and I/we authorize the Director of the United States Patent and Trademark Office or foreign equivalent to issue the Letters Patent or similar legal protection to the Assignee."

We authorize the U.S. Attorneys handling this matter in the U.S. and the Assignee, its successors and assigns, to insert in this instrument the filing date(s) and application numbers when ascertained. We further authorize the Assignee, its successors and assigns, or anyone it may properly designate, to apply for Letters Patent or similar legal protection, in its own name if desired, in the above named countries and jurisdictions and appoint Assignee the common representative in the above-identified international application and any international application for the invention.

We represent to the Assignee, its successors and assigns, that we shall not execute any writing or do any act whatsoever conflicting with this Assignment. We, our executors or administrators, will at any time upon request, without additional consideration, but at the expense of the Assignee, its successors and assigns, execute and deliver to Assignee or its legal representatives such additional writings and do such additional acts as the Assignee, its successors and assigns, may deem desirable to perfect its enjoyment of this grant, and render all assistance in making application for and obtaining, maintaining, and enforcing the Letters Patent or similar legal protection on the invention in any and all countries and jurisdictions, including without limitation providing testimony in any related interference, litigation or proceeding. To the extent that we, our executors or administrators are unable or unavailable to execute and deliver to Assignee or its legal representatives such additional writings and do such additional acts as Assignee, its successors and assigns may deem desirable to perfect its enjoyment of this grant, and render all assistance in making application for and obtaining, maintaining, and enforcing the Letters Patent or similar legal protection on the invention in any and all countries and jurisdictions, we, our executors or administrators hereby authorize Assignee, its successors and assigns to act on our behalf.

DF212023US

validity of the remaining provisions will not be affected by such holding and the part held unenforceable in or in conflict with the law of one jurisdiction will remain in effect for other jurisdictions until held unenforceable or in conflict with the law of that jurisdiction.

YU, Kun  
YU, Kun  
(Inventor / Assignor)

2021.8.17  
Date

LIU, Changming  
LIU, Changming  
(Inventor / Assignor)

2021.8.17  
Date

ZHANG, Xinyu  
ZHANG, Xinyu  
(Inventor / Assignor)

2021.8.17  
Date

## **SCORE Placeholder Sheet for IFW Content**

Application Number: 17964190

Document Date: 10/12/2022

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