

Doc Code: FAI.REQ

Document Description: Request First Action Interview

PTO/SB/413C (05-11)

Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U. S. DEPARTMENT OF COMMERCE

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REQUEST FOR FIRST ACTION INTERVIEW (FULL PILOT PROGRAM)

Attorney Docket Number: 131815-255190_P167C2DC	Application Number (if known):	Filing date: May 18, 2020
First Named Inventor: Smith, David D.	Title: SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY	

APPLICANT HEREBY REQUESTS A FIRST ACTION INTERVIEW IN THE ABOVE-IDENTIFIED APPLICATION. See Instruction Sheet on page 2.

1. The application must contain three (3) or fewer independent claims and twenty (20) or fewer total claims.
2. The application must not contain any multiple dependent claims.
3. By filing this request:

Applicant is agreeing to make an election without traverse if the Office determines that the claims are not obviously directed to a single invention; and

Applicant is agreeing not to request for a refund of the search fee and any excess claims fee paid in the application after the mailing or notification of the pre-interview communication prepared by the examiner.

4. Other attachments: _____

Signature /Justin K. Brask/	Date May 18, 2020
Name (Print/Typed) Justin K. Brask	Registration Number 61,080
Note: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required in accordance with 37 CFR 1.33 and 11.18. Please see 37 CFR 1.4(d) for the form of the signature. If necessary, submit multiple forms for more than one signature, see below*.	
☐ *Total of _____ forms are submitted.	

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 hours 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.

Instruction Sheet for Request for First Action Interview (Full Pilot Program)
(Not to be Submitted to the USPTO)

A grantable request must meet the following conditions:

1. The application must be a new non-reissue utility application filed under 35 U.S.C. 111(a) or an international application that has entered the national stage in compliance with 35 U.S.C. 371(c).
2. The application must contain three (3) or fewer independent claims and twenty (20) or fewer total claims. The application may not contain any multiple dependent claims.
3. The request must be filed electronically using the Office's electronic filing system, EFS-Web.
4. The claims must be directed to a single invention. If the Office determines that the claims are directed to multiple inventions (e.g., in a restriction requirement), the applicant must make an election without traverse.
5. The request must be filed at least one day before a first Office action on the merits of the application appears in the Patent Application Information Retrieval (PAIR) system (*i.e.*, at least one day prior to the date when a first Office action on the merits, notice of allowability or allowance, or action under Ex parte Quayle, 1935 Dec. Comm'r Pat. 11 (1935) appears in the PAIR system). Applicant may check the status of the application using the PAIR system.
6. The request for a first action interview must include a statement that applicant agrees not to file a request for a refund of the search fee and any excess claims fees paid in the application after the mailing or notification of the Pre-Interview Communication. Any petition for express abandonment under 37 CFR 1.138(d), and request for a refund of the search fee and any excess claims fees, filed after the mailing or notification of the Pre-Interview Communication will not be granted.

For more information, see notice "Full First Action Interview Pilot Program" available on the USPTO web site at http://www.uspto.gov/patents/init_events/faipp_full.jsp

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 disclosure of these records is required by the Freedom of Information Act.
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 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.

Electronic Acknowledgement Receipt	
EFS ID:	39472788
Application Number:	16877255
International Application Number:	
Confirmation Number:	2637
Title of Invention:	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY
First Named Inventor/Applicant Name:	David D. Smith
Customer Number:	149776
Filer:	Justin K. Brask/Blanche Niksich
Filer Authorized By:	Justin K. Brask
Attorney Docket Number:	131815-255190_P167C2DC
Receipt Date:	18-MAY-2020
Filing Date:	
Time Stamp:	19:24:47
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	7923P167C2DC_ADS.pdf	132746	no	9
			ea98a7ca7aaa7911c48169fe6c8b7e1e0cdd60e0		

Warnings:

Information:					
This is not an USPTO supplied ADS fillable form					
2		7923P167C2DC_APPLN.pdf	119852 985f01924f1c9c50604e37a6393566d1ec70ec0e	yes	23
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	19	
	Claims		20	22	
	Specification		23	23	
Warnings:					
Information:					
3	Drawings-only black and white line drawings	7923P167C2DC_Figs.pdf	334838 eda37c7ba9b8ebbb70987ed5a8d39490e0b69edcf	no	6
Warnings:					
Information:					
4	Oath or Declaration filed	7923P167C2DC_Decs.pdf	5276674 709f9576e36c206f5b087f37ec172a3f073904b1	no	3
Warnings:					
Information:					
5	First Action Interview - Enrollment Request	7923P167C2DC_FAI.pdf	568199 9a7f296866622081867c2c197436347bb17f107b	no	3
Warnings:					
Information:					
Total Files Size (in bytes):			6432309		

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 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.

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.

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC
		Application Number	
Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		
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. 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.			

Secrecy Order 37 CFR 5.2:

☐ 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.)

Inventor Information:

Inventor 1					Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	David	D.	Smith		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Campbell	State/Province	CA	Country of Residence	US
Mailing Address of Inventor:					
Address 1		426 N. Milton Avenue			
Address 2					
City	Campbell	State/Province	CA		
Postal Code	95008	Country	US		
Inventor 2					Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Tim		Dennis		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Canton	State/Province	TX	Country of Residence	US
Mailing Address of Inventor:					
Address 1		1032 Van Zandt County Road #2309			
Address 2					
City	Canton	State/Province	TX		
Postal Code	75103	Country	US		
Inventor 3					Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Russelle	De Jesus	Tabajonda		
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC
		Application Number	
Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		

City	Banlic Cabuyao City, Laguna	Country of Residence ⁱ	PH
Mailing Address of Inventor:			
Address 1	Block 10B Lot 11 Gran Seville Subdivision		
Address 2			
City	Banlic Cabuyao City, Laguna	State/Province	
Postal Code		Country ⁱ	PH
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button. Add			

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ An Address is being provided for the correspondence Information of this application.			
Customer Number	149776		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		
Attorney Docket Number	131815-255190_P167C2DC	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	6	Suggested Figure for Publication (if any)	

Filing By Reference:

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

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC
		Application Number	
Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		

Publication Information:
☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

Request Not to Publish. 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 **has not and will not** 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.

Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	149776		

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		Remove		
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)		
	Continuation of	16228165	2018-12-20		
Prior Application Status	Patented		Remove		
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
16228165	Division of	15876927	2018-01-22	10170642	2019-01-01
Prior Application Status	Patented		Remove		
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
15876927	Continuation of	15213273	2016-07-18	9899542	2018-02-20
Prior Application Status	Patented		Remove		
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
15213273	Continuation of	14579935	2014-12-22	9520507	2016-12-13

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC
		Application Number	
Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** 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)ⁱ 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 ⁱ	Filing Date (YYYY-MM-DD)	Access Code ^j (if applicable)

[Remove](#)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ 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.

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC
		Application Number	
Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		

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.

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC
		Application Number	
Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		

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.

Applicant 1

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.

Clear

- ☒ 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 SunPower Corporation

Mailing Address Information For Applicant:

Address 1 77 Rio Robles

Address 2

City San Jose

State/Province

CA

Country US

Postal Code

95134

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.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC	
		Application Number		
Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY			

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. ☐

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 ⁱ		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	/Justin K. Brask/		Date (YYYY-MM-DD)	2020-05-18
First Name	Justin K.	Last Name	Brask	Registration Number
				61,080

Additional Signature may be generated within this form by selecting the Add button.

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	131815-255190_P167C2DC
		Application Number	
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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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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.

7. The solar cell of claim 1, further comprising:
 - a second emitter region having metal impurities formed over the silicon substrate, wherein the second emitter region is formed over the back side of solar; and
 - a second metal contact formed over the second emitter region.
8. The solar cell of claim 1, further comprising:
 - a second dielectric region formed over the silicon substrate, wherein the second dielectric region is formed over the back side of solar;
 - a second emitter region having metal impurities formed over the second dielectric region; and
 - a second metal contact formed over the second emitter region.
9. The solar cell of claim 8, wherein the second emitter region comprises polysilicon.
10. A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
 - a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the front side of the solar cell;
 - a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;
 - a first emitter region having metal impurities formed over the dielectric region; and
 - a first metal contact formed over the first emitter region.

11. The solar cell of claim 10, wherein the portion of the silicon substrate comprises N-type dopants.

12. The solar cell of claim 10, wherein the portion of the silicon substrate comprises phosphorus.

13. The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants.

14. The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron.

15. The solar cell of claim 10, wherein the first emitter region comprises polysilicon.

16. The solar cell of claim 10, further comprising:
a second emitter region having metal impurities formed over the dielectric region; and
a second metal contact formed over the second emitter region.

17. The solar cell of claim 16, wherein the second emitter region is separate from the first emitter region.

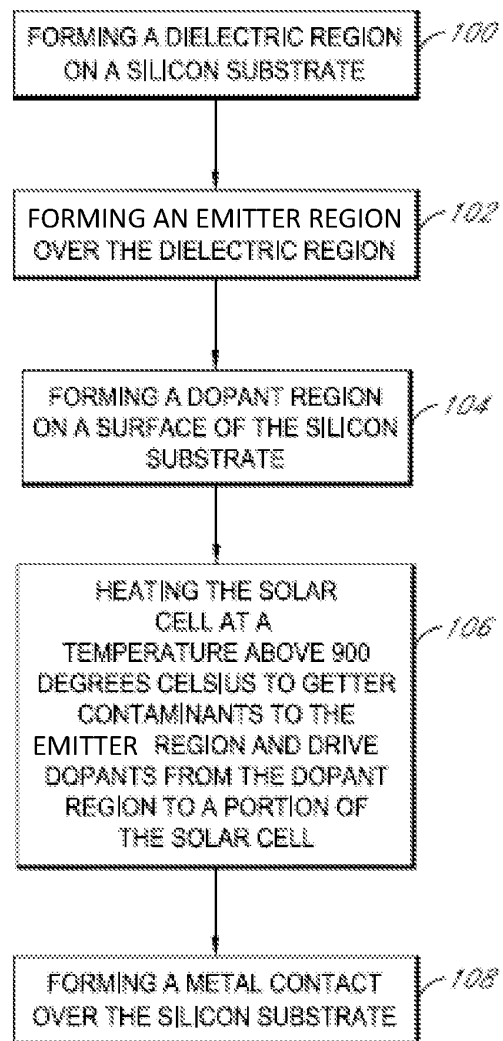
18. The solar cell of claim 16, wherein a trench region separates the first emitter region from the second emitter region.

19. The solar cell of claim 16, wherein the second emitter region comprises polysilicon.

20. The solar cell of claim 16, wherein the first emitter region comprises a P-type doped polysilicon region and the second emitter region comprises a N-type doped polysilicon region.

ABSTRACT OF THE DISCLOSURE

A method of fabricating a solar cell can include forming a dielectric region on a silicon substrate. The method can also include forming an emitter region over the dielectric region and forming a dopant region on a surface of the silicon substrate. In an embodiment, the method can include heating the silicon substrate at a temperature above 900 degrees Celsius to getter impurities to the emitter region and drive dopants from the dopant region to a portion of the silicon substrate.

*FIG. 1*

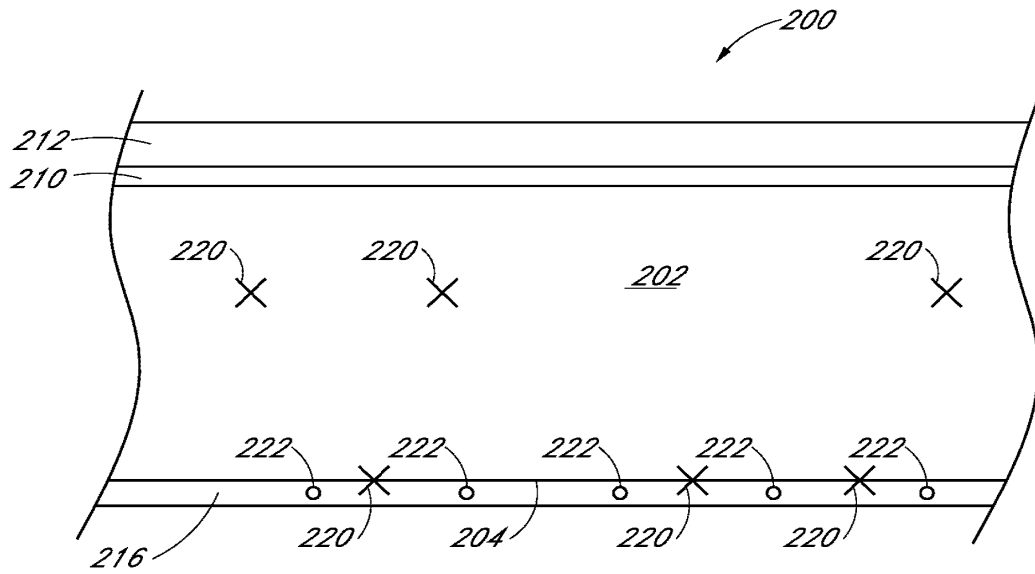


FIG. 2

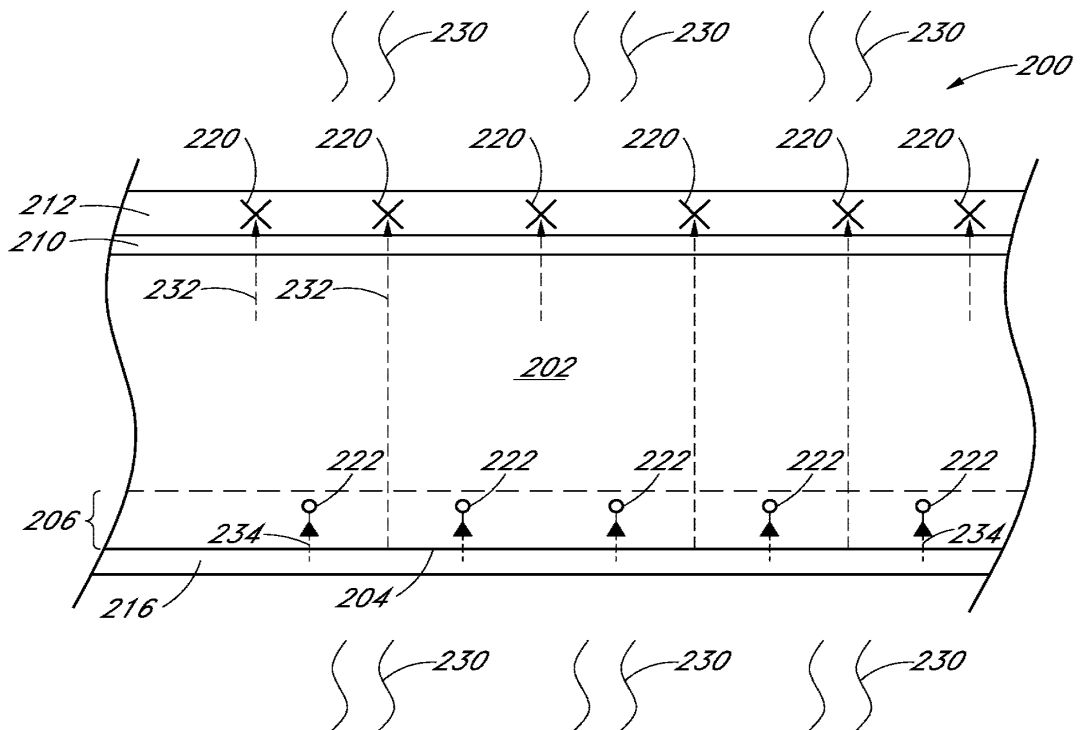


FIG. 3

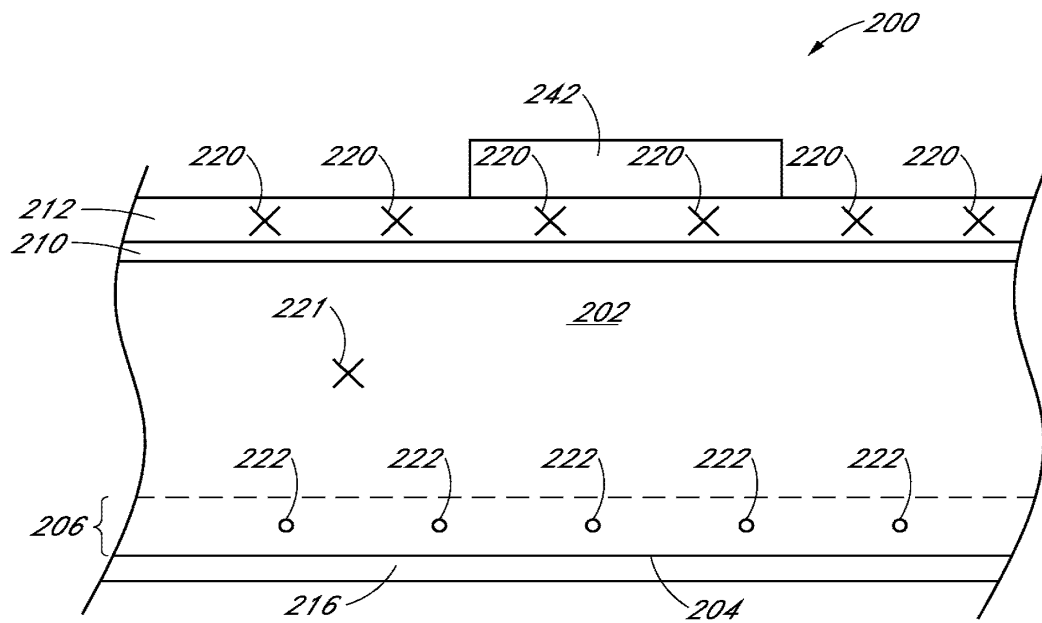


FIG. 4

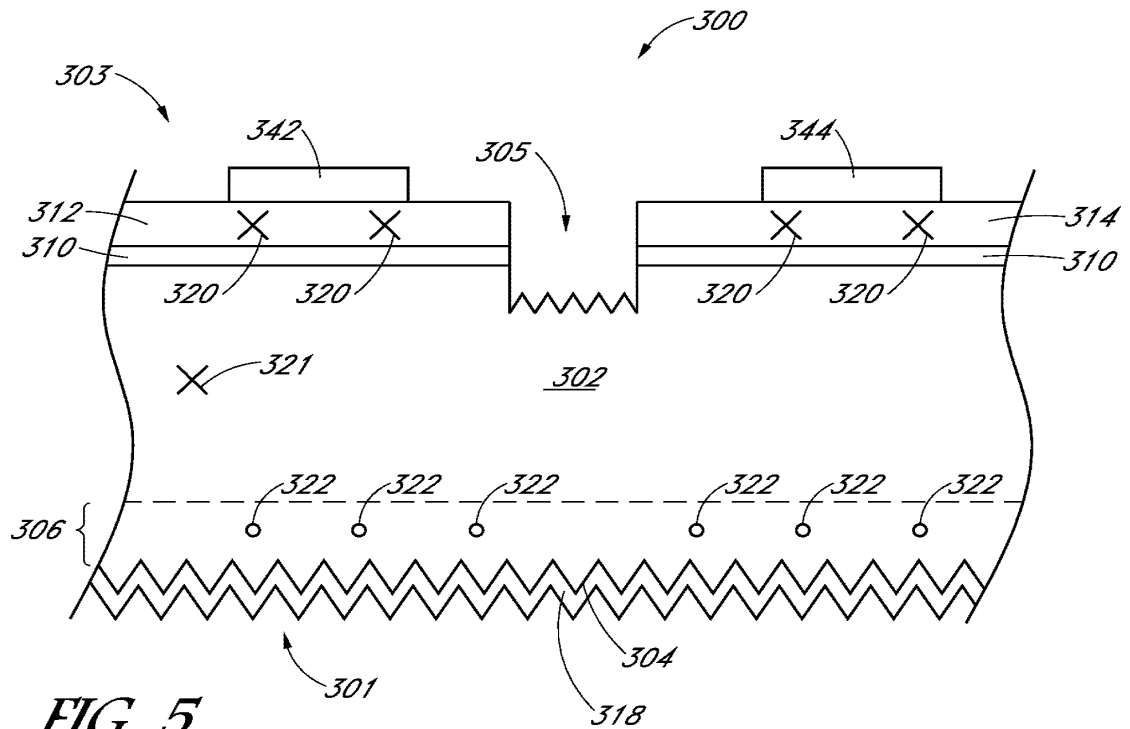


FIG. 5

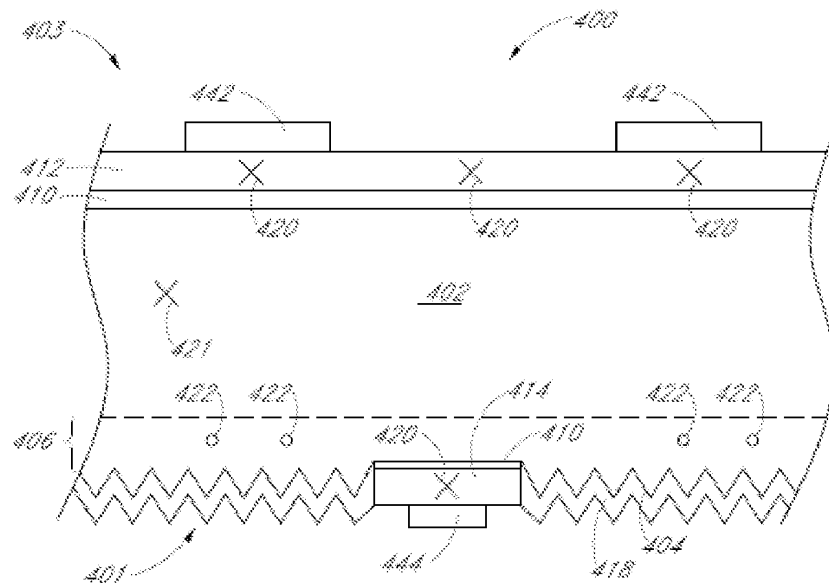


FIG. 6

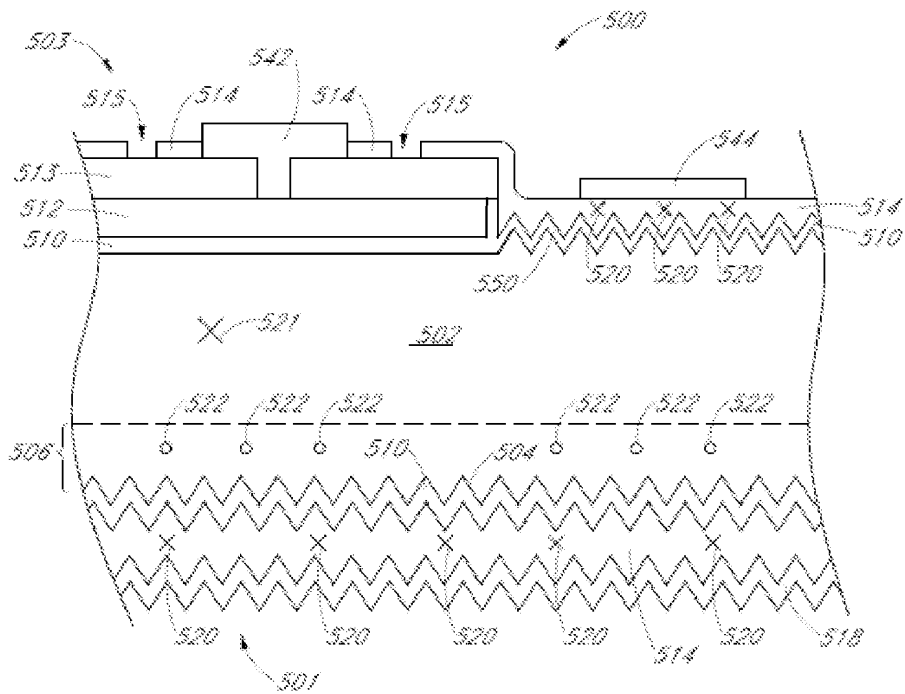
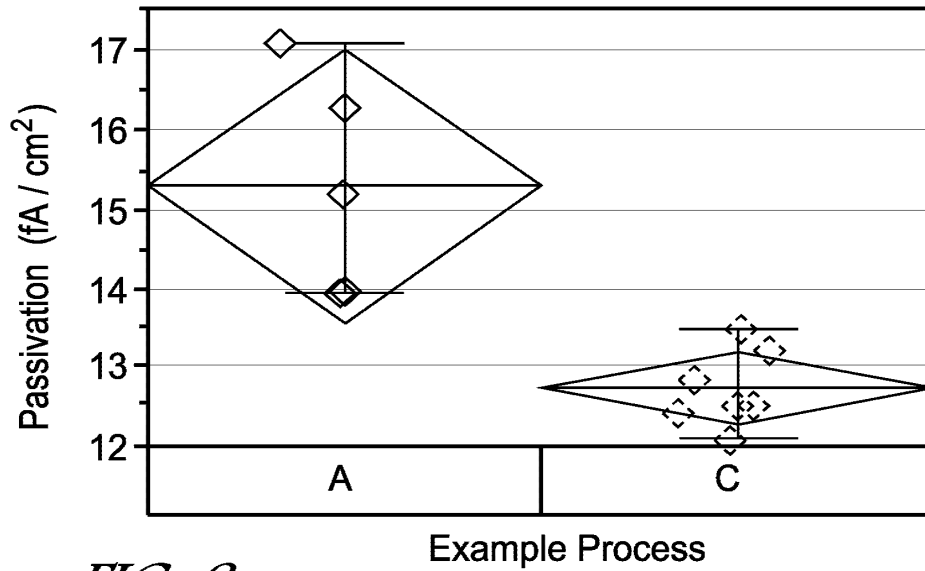
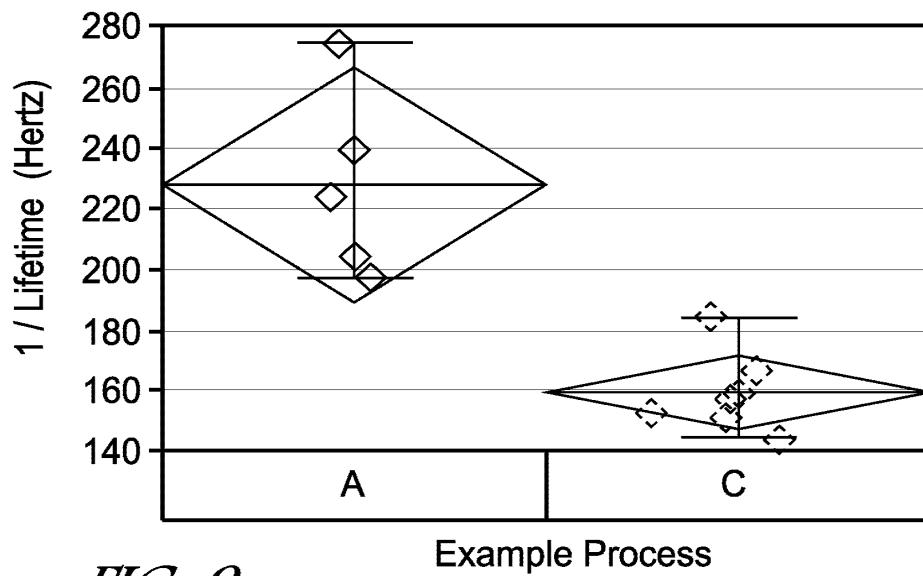
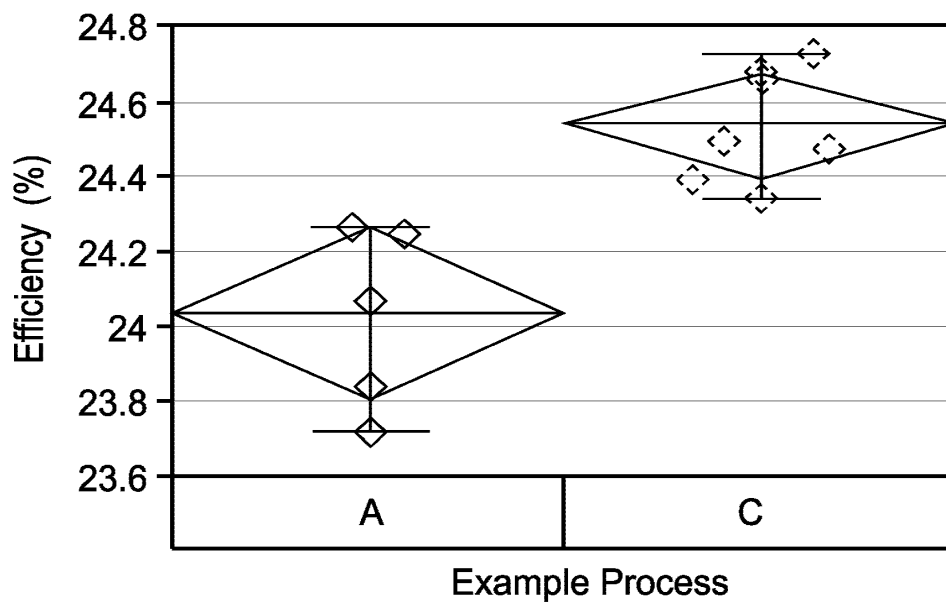


FIG. 7

*FIG. 8**FIG. 9*

*FIG. 10*

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
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**Title of
Invention**

SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY

As the below named inventor, I hereby declare that:

This declaration ☐ The attached application, or
is directed to:

☒ United States application or PCT international application number
14/579,935 filed on 12/22/2014

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
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LEGAL NAME OF INVENTOR

Inventor: David D. Smith Date (Optional): Jan-16-2015

Signature: David D. Smith

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7923P167

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Title of Invention	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY
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This declaration ☐ The attached application, or
is directed to:

☒ United States application or PCT international application number
14/579,935 filed on 12/22/2014

The above-identified application was made or authorized to be made by me.

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LEGAL NAME OF INVENTOR

Inventor: Tim Dennis Date (Optional): _____

Signature: Tim Dennis

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Title of
Invention

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As the below named inventor, I hereby declare that:

This declaration ☐ The attached application, or
is directed to:

☒ United States application or PCT international application number
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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.

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LEGAL NAME OF INVENTOR

Inventor: Russelle De Jesus Tabajonda Date (Optional): _____

Signature: 

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SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR
EFFICIENCY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. Patent Application No. 16/228,165, filed on December 20, 2018, which is a divisional of U.S. Patent Application No. 15/876,927, filed on January 22, 2018, now U.S. Patent No. 10,170,642, issued on January 1, 2019, which is a continuation of U.S. Patent Application No. 15/213,273, filed on July 18, 2016, now U.S. Patent No. 9,899,542, issued on February 20, 2018, which is a continuation of U.S. Patent Application No. 14/579,935, filed on December 22, 2014, now U.S. Patent No. 9,520,507, issued on December 13, 2016, the entire contents of which are hereby incorporated by reference herein.

BACKGROUND

[0002] Photovoltaic (PV) cells, commonly known as solar cells, are devices for conversion of solar radiation into electrical energy. Generally, solar radiation impinging on the surface of, and entering into, the substrate of a solar cell creates electron and hole pairs in the bulk of the substrate. The electron and hole pairs migrate to p-doped and n-doped regions in the substrate, thereby creating a voltage differential between the doped regions. The doped regions are connected to the conductive regions on the solar cell to direct an electrical current from the cell to an external circuit. When PV cells are combined in an array such as a PV module, the electrical energy collect from all of the PV cells can be combined in series and parallel arrangements to provide power with a certain voltage and current.

[0003] Efficiency is an important characteristic of a solar cell as it is directly related to the solar cell's capability to generate power. Accordingly, techniques for improving the fabrication process, reducing the cost of

manufacturing and increasing the efficiency of solar cells are generally desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Figure 1 illustrates a flow chart representation of an example method for fabricating of a solar cell, according to some embodiments.

[0005] Figures 2-4 illustrate cross-sectional views of example solar cells during the fabrication process of Figure 1, according to some embodiments.

[0006] Figure 5 illustrates a cross-sectional view of an example solar cell, according to some embodiments.

[0007] Figure 6 illustrates a cross-sectional view of another example solar cell, according to some embodiments.

[0008] Figure 7 illustrates a cross-sectional view of still another example solar cell, according to some embodiments.

[0009] Figure 8 illustrates a graph of example surface passivation measurements, according to some embodiments.

[0010] Figure 9 illustrates a graph of example 1/lifetime measurements, according to some embodiments.

[0011] Figure 10 illustrates a graph of example efficiency measurements, according to some embodiments.

DETAILED DESCRIPTION

[0012] The following detailed description is merely illustrative in nature and is not intended to limit the embodiments of the subject matter of the application or uses of such embodiments. As used herein, the word “exemplary” means “serving as an example, instance, or illustration.” Any implementation described herein as exemplary is not necessarily to be construed as preferred or advantageous over other implementations. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

[0013] This specification includes references to “one embodiment” or “an embodiment.” The appearances of the phrases “in one embodiment” or “in an embodiment” do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

[0014] Terminology. The following paragraphs provide definitions and/or context for terms found in this disclosure (including the appended claims):

[0015] “Comprising.” This term is open-ended. As used in the appended claims, this term does not foreclose additional structure or steps.

[0016] “Configured To.” Various units or components may be described or claimed as “configured to” perform a task or tasks. In such contexts, “configured to” is used to connote structure by indicating that the units/components include structure that performs those task or tasks during operation. As such, the unit/component can be said to be configured to perform the task even when the specified unit/component is not currently operational (e.g., is not on/active). Reciting that a unit/circuit/component is “configured to” perform one or more tasks is expressly intended not to invoke 35 U.S.C. §112, sixth paragraph, for that unit/component.

[0017] “First,” “Second,” etc. As used herein, these terms are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.). For example, reference to a “first” emitter region does not necessarily imply that this emitter region is the first emitter region in a sequence; instead the term “first” is used to differentiate this emitter region from another emitter region (e.g., a “second” emitter region). In an embodiment, an emitter region can be a doped region of a solar cell for collecting positive and negative charge carriers. In an example, the emitter region can be a doped polysilicon region. In one example, the emitter region can be a P-type doped polysilicon region or an N-type doped polysilicon region.

[0018] “Based On.” As used herein, this term is used to describe one or more factors that affect a determination. This term does not foreclose additional factors that may affect a determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase “determine A based on B.” While B may be a factor that affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.

[0019] “Coupled” – The following description refers to elements or nodes or features being “coupled” together. As used herein, unless expressly stated otherwise, “coupled” means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically.

[0020] In addition, certain terminology may also be used in the following description for the purpose of reference only, and thus are not intended to be limiting. For example, terms such as “upper”, “lower”, “above”, and “below” refer to directions in the drawings to which reference is made. Terms such as “front”, “back”, “rear”, “side”, “outboard”, and “inboard” describe the orientation and/or location of portions of the component within a consistent but arbitrary frame of reference which is made

clear by reference to the text and the associated drawings describing the component under discussion. Such terminology may include the words specifically mentioned above, derivatives thereof, and words of similar import.

[0021] In the following description, numerous specific details are set forth, such as specific operations, in order to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to one skilled in the art that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known techniques are not described in detail in order to not unnecessarily obscure embodiments of the present disclosure.

[0022] This specification first describes solar cell fabrication techniques to improve solar cell lifetime, passivation and/or efficiency followed by a description of example solar cells fabricated according to the disclosed techniques. Various embodiments are provided throughout followed by example results from the disclosed techniques.

[0023] Turning now to Figure 1, a method for fabricating a solar cell is shown, according to some embodiments. In various embodiments, the method of Figure 1 can include additional (or fewer) blocks than illustrated. For example, in some embodiments, the silicon region formed at block 102 can be heated to form a polysilicon region after step 102 but before to the heating step of block 106.

[0024] At 100, a dielectric can be formed on a silicon substrate of a solar cell. In some embodiments, the silicon substrate can be cleaned, polished, planarized, and/or thinned or otherwise processed prior to the formation of the dielectric region. In an embodiment, the silicon substrate can be single-crystalline or a multicrystalline silicon substrate. In an embodiment, the silicon substrate can be a N-type silicon substrate. In an embodiment, the dielectric can be a tunnel oxide. In one embodiment, the dielectric can be silicon dioxide. In an embodiment, the dielectric region can be grown and/or formed through a thermal process.

[0025] At 102, an emitter region can be formed over the dielectric region. In an embodiment, the emitter region can be an amorphous silicon region. In some embodiments, the amorphous silicon region can be grown over the dielectric region. In an embodiment, the emitter region can be polysilicon. In an embodiment, the emitter region can be grown and/or formed through a thermal process. In an example, an amorphous silicon region can be formed over the dielectric region and heated to form a polysilicon region.

[0026] An emitter dopant region can be deposited over the emitter region through a deposition process. The emitter dopant region can comprise a dopant, such as a positive-type doping material such as boron or a negative-type doping material such as phosphorous.

[0027] Although the dielectric region and/or the emitter region are described as being grown by a thermal process or deposited through conventional deposition process, respectively, as with any other formation, deposition, or growth process step described or recited here, each layer or substance can be formed using any appropriate process. For example, a chemical vapor deposition (CVD) process, low-pressure CVD (LPCVD), atmospheric pressure CVD (APCVD), plasma-enhanced CVD (PECVD), thermal growth, sputtering, as well as any other desired technique can be used where formation is described. Thus, and similarly, the emitter dopant region can be formed on the substrate by a deposition technique, implant process, sputter, or print process, such as inkjet printing or screen printing.

[0028] In an embodiment, a heating process can be performed to drive dopants from the emitter dopant region to the emitter region. In one example, the heating process can drive dopants from the emitter dopant region to a polysilicon region to form a doped polysilicon region. In an embodiment, the doped polysilicon region can be doped with a P-type dopant such as boron or an N-type dopant such as phosphorus. In one example, the doped polysilicon regions can be formed in alternating P-type and N-type regions. In some embodiments, the heating to drive dopants from the emitter dopant

region to the emitter region, can be performed at a temperature below 900 degrees Celsius.

[0029] At 104, a dopant region can be formed over a surface of the silicon substrate. In an embodiment, the dopant region can be grown and/or formed through a thermal process. In one example, the dopant region can be formed over a surface, e.g., on the front side of a solar cell, and subsequently a heating process can be performed to drive dopants into a portion of the silicon substrate. In an embodiment, the portion of the silicon substrate can have a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ after the heating process as discussed in block 106.

[0030] In one embodiment, the dopant region can be an N-type dopant, e.g., phosphorus. In an embodiment, the surface of the silicon substrate over which the dopant region is formed can be a front side, back side, or both on the front and back sides of the solar cell. Figure 2 shows an example solar cell having the dielectric region, emitter region and dopant region described above.

[0031] Although the dopant region is described as being grown by a thermal process or deposited through conventional deposition process, respectively, as with any other formation, deposition, or growth process step described or recited here, each layer or substance can be formed using any appropriate process. For example, a chemical vapor deposition (CVD) process, low-pressure CVD (LPCVD), atmospheric pressure CVD (APCVD), plasma-enhanced CVD (PECVD), thermal growth, sputtering, as well as any other desired technique can be used where formation is described.

[0032] Figure 2 illustrates an example solar cell after forming the dielectric region, emitter region, and dopant region, according to some embodiments. In an embodiment, a dielectric region 210 can be formed over a silicon substrate 202 of the solar cell 200. In an embodiment, the dielectric region 210 can be a tunnel oxide. In one example, the dielectric region 210 can be silicon dioxide. In an embodiment, an emitter region 212 can be formed on the dielectric region 210. In an embodiment and as noted above, the emitter region 212 can be amorphous silicon or polysilicon. In an

embodiment, the emitter region 212 can be a doped polysilicon. In an example, the doped polysilicon can be N-type doped or P-type doped polysilicon.

[0033] In an embodiment, a dopant region 216 can be formed on a surface 204 of silicon substrate 202. In an embodiment, the dopant region 216 can be formed to dope the surface 204 (e.g., at block 106 below) to repel charge carriers and prevent and/or reduce recombination at the surface 204 of the solar cell 200. In an example, the surface 204, can be on a front side and/or a back side of the solar cell. In one example, the dopant region 216 can be a N-type dopant region, such as phosphorus. In an embodiment, the dopant region 216 can have positive or negative type dopants 222.

[0034] In an embodiment, the silicon substrate 202 can have contaminants and/or impurities 220, for example metal contaminants and/or metal impurities, such as iron, nickel and/or chromium among others. Metal impurities can be detrimental to the electrical conduction of the solar cell as these impurities can be sources of recombination, resulting in poor lifetime, surface passivation and/or lower solar cell efficiency. In an embodiment, the impurities 220 can be located at or near a surface 204 of the silicon substrate 202. In an embodiment, the impurities 220 can be located within the silicon substrate 202 as shown. As referred throughout, contaminants and/or impurities can be used interchangeably.

[0035] The emitter regions 212, e.g., polysilicon regions, can be a good sink and/or trap for the metal impurities 220 discussed above. A gettering process can be used to trap the metal impurities 220 in the emitter regions 212, reducing recombination within the silicon substrate 202 and improving overall solar cell lifetime. Oxides and/or tunnel oxides, such as the dielectric region 210 of Figure 2, can be barriers to gettering of the metal impurities 220 to emitter regions 212. In one example, heating at temperature at 900 degrees Celsius or below can be insufficient to diffuse metal impurities through a tunnel oxide and into a polysilicon region. Thus, in an embodiment, heating at temperatures above 900 degrees Celsius can include gettering metal

impurities 220 through the dielectric region 210, e.g., tunnel oxide, to into the emitter region 212, e.g., polysilicon regions, as discussed in detail at 106 of Figure 1 below.

[0036] At 106, the solar cell can be heated at a temperature above 900 degrees Celsius. In an embodiment, the heating can drive dopants from the dopant region to a portion of the silicon substrate. In one embodiment, the heating can include performing an annealing process on the silicon substrate. In an example, the heating can drive dopants to the portion of the silicon substrate located above the surface, as shown in Figure 3. In some embodiments, the surface can be on the front side, back side or both on the front and back side of the solar cell. In an embodiment, the heating can include gettering contaminants, e.g. metal impurities and/or metal contaminants, from the substrate to the emitter region. In an example, the metal impurities and/or metal contaminants can be iron, nickel and/or chromium among others.

[0037] In one example, the heating can include placing the solar cell in thermal tool, e.g., a thermal furnace or oven among others, and raising the temperature in the thermal tool to 975 degrees Celsius or above.

[0038] In an embodiment, the heating can be the last heating step in the solar cell fabrication process. In one embodiment, the heating can be the only heating step in the fabrication process. In some embodiments, at least one other heating step can be performed before the heating process of block 106. In one example, the other heating process, aside from the heating process of block 106, can include heating the solar cell to temperature below 900 degrees Celsius. In an example, the heating process below 900 degrees Celsius can be performed before the heating process at 106. In an embodiment, the heating performed at 106 can be performed at the highest temperature among other heating steps performed in the solar cell fabrication process. Figure 3 illustrates the heating process described above.

[0039] Figure 3 illustrates heating the solar cell of Figure 2, according to some embodiments. In an embodiment, the heating 230 can include heating the

solar cell 200 above 900 degrees Celsius. In an example, the heating can include placing the solar cell 200 into a thermal tool, e.g., thermal furnace or oven among others, and raising the temperature within the thermal tool to 975 degrees Celsius or higher. In an embodiment, the heating 230 can drive 234 the dopants 222 from the dopant region 216 to a portion 206 of the silicon substrate 202. In an example, the dopant concentration of the portion 206 of the silicon substrate 202 can be approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ after the heating. In an embodiment, the portion 206 of the silicon substrate 202 can be above, as shown, the surface 204 of the silicon substrate 202. In an embodiment, the heating 230 can getter 232 contaminants 220 from, or nearby, the surface 204 of the silicon substrate 202 and/or from within the silicon substrate 202 to the emitter region 212. In an embodiment, the heating 230 can getter 232 the containments 220 through the dielectric region 210 to the emitter region 212.

[0040] At 108, a metal contact can be formed over the silicon substrate. In an embodiment, the metal contact can be formed on the emitter region. In some embodiments, the metal contact can be formed by a metallization process. In one example, the metallization process can include plating and/or electroplating the metal contact to the emitter region. In some embodiments, the metal contact can be formed by printing and/or foil-based metallization techniques. Figure 4 illustrates an example silicon substrate after to forming the metal contact. Also Figure 4 illustrates a single metal contact, for example, which can be on a front side or back side of the solar cell. In an embodiment, multiple metal contacts can exist. In an example, positive and negative metal contacts can be formed in an interdigitated pattern.

[0041] With reference to Figure 4, the solar cell of Figure 3 is shown after forming a metal contact, according to some embodiments. In an embodiment, the metal contact 242 can be formed on the emitter region 212, e.g. over the silicon substrate 202. In an example, the metal contact 242 can be formed by an electroplating process, printing process or a foil-based metallization process among others. In an embodiment, the metal contact 242

can be a positive or negative metal contact. As shown in Figure 4 a single metal contact is illustrated for example, which can be on a front side or back side of the solar cell. In an example, multiple metal contacts, e.g. some positive and others negative, can exist. In one embodiment, the silicon substrate 202 can have some impurities 221 remaining after the heating 230 of Figure 3.

[0042] Figure 5 illustrates a cross-section of a portion of a solar cell formed from the method of Figures 1-4, according to some embodiments. The solar cell 300 can have a front side 301 which faces the sun during normal operation and a back side 303 opposite the front side 301. The solar cell 300 can include a silicon substrate 302. In an embodiment, the silicon substrate 302 can be an N-type silicon substrate. In an embodiment, a portion 306 of the silicon substrate 302 can have a doping concentration 322 of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$.

[0043] The solar cell 300 can have a dielectric region 310 formed over the silicon substrate 302. In an embodiment, the dielectric 310 can be a tunnel oxide. In some embodiments, the dielectric region 310 can be silicon dioxide. In an embodiment, the solar cell 300 can have first and second emitter regions 312, 314. In an example, the first and second emitter regions 312, 314 can be P-type and N-type doped polysilicon regions, respectively. In an example, impurities and/or contaminants 320, e.g. metal impurities 320 and/or metal contaminants, can be located in the first and second emitter regions 312, 314 as shown. In one embodiment, the silicon substrate 302 can have some impurities 321 remaining after the gettering process.

[0044] In an embodiment, the solar cell 300 can have first and second metal contacts 342, 344 formed on the first and second emitter regions 312, 314, respectively. In some embodiments, a trench region 305 can be formed, which can separate the first and second emitter regions 312, 314. In an embodiment, the solar cell 300 can have a textured surface 304 on the front side 301. In an example, the textured surface 304 can be a surface which can provide additional light absorption. In an embodiment, the portion 306 of the

silicon substrate 302 can be formed above a textured surface 304 as shown. In some embodiments, the trench region 305 can also be textured, similar to the textured surface 304, for additional light absorption from the back side 303 of the solar cell 300. In some embodiments, an anti-reflective region (ARC) 318 can be formed over the textured surface 304 of the solar cell 300. In some embodiments, the anti-reflective region 318 can be silicon nitride.

[0045] In an embodiment, the solar cell 300 can be a back contact solar cell, for example, as shown in Figures 5 and 7.

[0046] With reference to Figure 6, a front contact solar cell formed from the method of Figures 1-4 is shown, according to some embodiments. The solar cell 400 can have a front side 401 which faces the sun during normal operation and a back side 403 opposite the front side 401. The solar cell 400 can include a silicon substrate 402. In an embodiment, the silicon substrate 402 can be a N-type silicon substrate. In an embodiment, a portion 406 of the silicon substrate 402 can have a doping concentration 422 of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$.

[0047] The solar cell 400 can have a dielectric 410 formed over the silicon substrate 402. In an embodiment, the dielectric 410 can be a tunnel oxide. In some embodiments, the dielectric 410 can be silicon dioxide. In an embodiment, the solar cell 400 can have first and second emitter regions 412, 414. In some embodiments, the first emitter region 412 can be formed on the back side 403 of the solar cell 400 and the second emitter region 414 can be formed on the front side 401 of the solar cell 400. In an example, the first and second emitter regions 412, 414 can be P-type and/or N-type doped polysilicon regions.

[0048] In an embodiment, the solar cell 400 can have first and second metal contacts 442, 444 formed on the first and second emitter regions 412, 414, respectively. In an embodiment, the solar cell 400 can have a textured surface 404 on the front side 401. In an example, the textured surface 404 can be a surface which can provide additional light absorption. In an embodiment, the portion 406 of the silicon substrate 402 can be above a textured surface

404 as shown. In some embodiments, an anti-reflective region (ARC) 418 can be formed over the textured surface 404 of the solar cell 400. In some embodiments, the anti-reflective region 418 can be silicon nitride.

[0049] In an example, impurities and/or contaminants 420, e.g. metal impurities and/or contaminants, can be located in the first and second emitter regions 412, 414. In one embodiment, the silicon substrate 402 can have some impurities 421 remaining after the gettering process.

[0050] Figure 7 illustrates still another solar cell formed from the method of Figures 1-4, according to some embodiments. The solar cell 500 can have a front side 501 which faces the sun during normal operation and a back side 503 opposite the front side 501. The solar cell 500 can include a silicon substrate 502. In an embodiment, the silicon substrate 502 can be a N-type silicon substrate. In an embodiment, a portion 506 of the silicon substrate 502 can have a doping concentration 522 of approximately equal to or less than $2 \times 10^{18} \text{ cm}^{-3}$.

[0051] The solar cell 500 can have a dielectric region 510 formed over the silicon substrate 502. In an embodiment, the dielectric 510 can be a tunnel oxide. In an embodiment, the dielectric region 510 can be silicon dioxide. In an embodiment, the solar cell 500 can have first and second emitter regions 512, 514. In an example, the first and second emitter regions 512, 514 can be P-type and/or N-type doped polysilicon regions, respectively. In one embodiment, the second emitter region 514 can be at least partially formed over the first emitter region 512, as shown. In an embodiment, a second dielectric region 513 can be formed over the first emitter region 512, e.g. to insulate the first emitter region 512 from the second emitter region 514. In some embodiments, the second dielectric region 513 can also be silicon dioxide. In an embodiment, an opening 515 can isolate the second emitter region 514 from the first metal contact 542.

[0052] In some embodiments, the dielectric region 510 and second silicon region 514 can be formed over the back side 501 of the solar cell 500.

[0053] In an example, impurities and/or contaminants 520, e.g. metal impurities and/or contaminants, can be located in the second emitter region 512 as shown. In an example, the metal impurities 520 can be iron, nickel and/or chromium among others. In one embodiment, the silicon substrate 502 can have some impurities 521 remaining after the heating process.

[0054] In an embodiment, the solar cell 500 can have first and second metal contacts 542, 544 formed on the first and second emitter regions 512, 514, respectively. In one embodiment, the solar cell 500 can have a textured surface 504 on the front side 501 and/or a textured surface 550 on the back side 503 as shown. In an example, the textured surfaces 504, 550 can be surfaces which can provide additional light absorption. In an embodiment, the portion 506 of the silicon substrate 502 can be above a textured surface 504 as shown. In some embodiments, an anti-reflective region 518 can be formed over the textured surface 504 of the solar cell 500.

Example Process	Temp	Surface Dopant Conc.	Gettering Location	Surface Passivation	Lifetime	Efficiency
A	≤ 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	non-poly	2 fA/cm^2	$\sim 3 \text{ msec}$	Baseline
B	≤ 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	non-poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline
C	> 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	poly	2 fA/cm^2	$\sim 10 \text{ msec}$	+0.5 % abs.
D	> 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline

Table 1. Example Processes for Solar Cell Fabrication

[0055] Turning now to Table 1, a table is shown listing Temperature and Surface Dopant Concentration and output results, such as Gettering Location, Surface Passivation, Lifetime and Efficiency, for example processes of fabricating solar cells.

[0056] The method of Figures 1-4 is exemplified in Example Process C of Table 1, where a surface, or a portion near the surface, of a silicon substrate was doped at approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and the

solar cell of Example Process C heated to a temperature above 900 degrees Celsius. The results from Example Process C are gettering in a polysilicon region of the silicon substrate, improved surface passivation at approximately 5 fA/cm², improved lifetime, e.g. typical of approximately 10 μsec, and a > 0.5 % efficiency increase as compared to other solar cells, e.g. referenced as the baseline efficiency.

[0057] In contrast, referring to Example Process A, a surface, or a portion near the surface, of the silicon substrate was doped at approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process A heated to a temperature below 900 degrees Celsius resulting in gettering in a non-polysilicon region of the solar cell, good surface passivation at approximately 2 fA/cm², poor lifetime, e.g. typical of approximately 3 μsec and no considerable, e.g., < 0.5%, efficiency increase from the baseline.

[0058] In another example, referring to Example Process B, a surface of the silicon substrate was doped at approximately $4 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process B heated to a temperature below 900 degrees Celsius resulting in gettering in a non-polysilicon region of the solar cell, poor surface passivation at approximately 5 fA/cm², good lifetime, e.g. typical of approximately 10 μsec and no considerable, e.g. < 0.5%, efficiency increase from the baseline.

[0059] In yet another example comparison, in Example Process D a surface of the silicon substrate was doped at approximately $4 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process D heated to a temperature above 900 degrees Celsius also resulted gettering in a polysilicon region of the silicon substrate, but poor surface passivation at approximately 5 fA/cm², good lifetime, e.g. typical of approximately 10 μsec and no considerable, e.g. < 0.5%, efficiency increase from the baseline.

[0060] In all Examples Processes A, B and D either the lifetime or surface passivation only was improved, and the Example Process C resulted in improved surface passivation, lifetime and efficiency.

[0061] With reference to Figures 8-10, example surface passivation, 1/lifetime and efficiency measurements, respectively, for solar cells fabricated using the methods of the Example Processes A and C of Table 1 is shown. The results from Figures 8-10 show that the surface passivation, lifetime and efficiency of solar cells fabricated using the method of Figures 1-4, e.g., Example Process C, have improved surface passivation, lifetime and higher efficiency measurements as compared to the solar cells of Example process A.

[0062] Figure 8 illustrates a graph of surface passivation measurements from solar cells fabricated using the Example Process A and C from Table 1. As shown, the Example Process C has lower passivation results as compared to Example Process A. Lower surface passivation is preferred for high efficiency solar cells. Thus, the Example Process C has improved surface passivation results as compared to Example Process A.

[0063] With reference to Figure 9, there is shown a graph of 1/lifetime measurements from solar cells fabricated using the Example Process A and C from Table 1. As shown, the Example Process C has higher lifetime, lower 1/lifetime results, as compared to Example Process A. Higher lifetime is preferred for high efficiency solar cells. Thus, the Example Process C has improved lifetime results as compared to Example Process A.

[0064] Figure 10 illustrates a graph of efficiency measurements from solar cells fabricated using the Example Process A and C from Table 1. As shown, the Example Process C has higher efficiency results as compared to Example Process A. Higher solar cell efficiency conversion is preferred to maximize the electricity conversion from collected light. Thus, the Example Process C has improved efficiency results over Example Process A.

[0065] The results of Figures 8-10 demonstrate that a solar cell fabrication technique of Figures 1-4 results in overall improvement for surface passivation, lifetime and efficiency from other techniques, e.g. Example Processes A, B and D.

[0066] Although specific embodiments have been described above, these embodiments are not intended to limit the scope of the present

disclosure, even where only a single embodiment is described with respect to a particular feature. Examples of features provided in the disclosure are intended to be illustrative rather than restrictive unless stated otherwise. The above description is intended to cover such alternatives, modifications, and equivalents as would be apparent to a person skilled in the art having the benefit of this disclosure.

[0067] The scope of the present disclosure includes any feature or combination of features disclosed herein (either explicitly or implicitly), or any generalization thereof, whether or not it mitigates any or all of the problems addressed herein. Accordingly, new claims may be formulated during prosecution of this application (or an application claiming priority thereto) to any such combination of features. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the appended claims.

CLAIMS

What is claimed is:

1. A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
 - a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the back side of the solar cell;
 - a first dielectric region formed over the silicon substrate, wherein the first dielectric region is formed over the front side of solar;
 - a first emitter region having metal impurities formed over the first dielectric region; and
 - a first metal contact formed over the first emitter region.
2. The solar cell of claim 1, wherein the portion of the silicon substrate comprises N-type dopants.
3. The solar cell of claim 1, wherein the portion of the silicon substrate comprises phosphorus.
4. The solar cell of claim 1, wherein the portion of the silicon substrate comprises P-type dopants.
5. The solar cell of claim 1, wherein the portion of the silicon substrate comprises boron.
6. The solar cell of claim 1, wherein the first emitter region comprises polysilicon.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 16/877,255	
APPLICATION AS FILED - PART I							
(Column 1)		(Column 2)		SMALL ENTITY		OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)		RATE(\$)	FEE(\$)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	300
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	660
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	760
TOTAL CLAIMS (37 CFR 1.16(i))	20	minus 20 = *				x 100 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2	minus 3 = *				x 460 =	0.00
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).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
			TOTAL			TOTAL	1720
* If the difference in column 1 is less than zero, enter "0" in column 2.							
APPLICATION AS AMENDED - PART II							
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY	
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus **	=	x =	x =	=
	Independent (37 CFR 1.16(h))	*	Minus ***	=	x =	x =	=
	Application Size Fee (37 CFR 1.16(s))						
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY	
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	RATE(\$)	ADDITIONAL FEE(\$)
	Total (37 CFR 1.16(i))	*	Minus **	=	x =	x =	=
	Independent (37 CFR 1.16(h))	*	Minus ***	=	x =	x =	=
	Application Size Fee (37 CFR 1.16(s))						
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY	
			TOTAL ADD'L FEE			TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** 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 found in the appropriate box in column 1.							



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16/877,255	05/18/2020	1757	0.00	131815-255190_P167C2DC	20	2

CONFIRMATION NO. 2637

FILING RECEIPT



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Power of Attorney: None

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This application is a CON of 16/228,165 12/20/2018 PAT 10658525
which is a DIV of 15/876,927 01/22/2018 PAT 10170642
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which is a CON of 14/579,935 12/22/2014 PAT 9520507

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

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.

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The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/877,255**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No
Title

SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY

Preliminary Class

136

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

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC

CONFIRMATION NO. 2637

FORMALITIES LETTER



149776

Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

Date Mailed: 05/28/2020

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A substitute specification in compliance with 37 CFR 1.52, 1.121(b)(3), and 1.125, is required. The substitute specification must be submitted with markings and be accompanied by a clean version (without markings) as set forth in 37 CFR 1.125(c) and a statement that the substitute specification contains no new matter (see 37 CFR 1.125(b)). The specification, claims, and/or abstract page(s) submitted is not acceptable and cannot be scanned or properly stored because:
 - The application papers (including any electronically submitted papers) are not in compliance with 37 CFR 1.52 because pages 15 contain text that is unreadable or of insufficient clarity. Application papers (including any electronically submitted papers) must be presented in a form having sufficient clarity and contrast between the background of the paper and the writing thereon to permit the Office to electronically reproduce the papers by use of digital imaging and optical character recognition. See 37 CFR 1.52(a)(1)(v).

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

- The statutory basic filing fee is missing.

- The application search fee must be submitted.
- The application examination fee must be submitted.
- Surcharge as set forth in 37 CFR 1.16(f) must be submitted.

The surcharge is due for any one of:

- late submission of the basic filing fee, search fee, or examination fee,
- late submission of inventor's oath or declaration,
- filing an application that does not contain at least one claim on filing, or
- submission of an application filed by reference to a previously filed application.

SUMMARY OF FEES DUE:

The fee(s) required within **TWO MONTHS** from the date of this Notice to avoid abandonment is/are itemized below. No entity status discount is in effect. If applicant is qualified for small entity status, a written assertion of small entity status must be submitted to establish small entity status. (See 37 CFR 1.27). If applicant is qualified for micro entity status, an acceptable Certification of Micro Entity Status must be submitted to establish micro entity status. (See 37 CFR 1.29 and forms PTO/SB/15A and 15B.)

- \$ **300** basic filing fee.
- \$ **160** surcharge.
- \$ **660** search fee.
- \$ **760** examination fee.
- \$(**0**) previous unapplied payment amount.
- \$ **1880** TOTAL FEE BALANCE DUE.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web, including a copy of this Notice and selecting the document description "Applicant response to Pre-Exam Formalities Notice".
<https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html>

For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at <http://www.uspto.gov/ebc>.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth 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.

/dmnguyen/

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Smith, et al.

Application No.: 16/877,255

Filed: May 18, 2020

For: SOLAR CELLS WITH IMPROVED
LIFETIME, PASSIVATION AND/OR
EFFICIENCY

Examiner: Unassigned

Art Unit: 1757

Confirmation No.: 2637

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

PETITION UNDER 37 CFR §1.84(a)(2) TO ACCEPT COLOR DRAWINGS

Dear Examiner:

In reply to the Notice to File Missing Parts of Nonprovisional Application mailed May 28, 2020, Applicants hereby submit a petition to accept color drawings in the above-referenced application. The color drawings are necessary as the only practical medium by which aspects of the claimed subject matter may be accurately conveyed.

In accordance with 37 CFR §1.84(a)(2)(i), the fee set forth in §1.17(h) is being submitted herewith.

In accordance with 37 CFR §1.84(a)(2)(ii), one set of color drawings is submitted since they are being filed electronically via EFS Web. No new matter has been introduced.

In accordance with 37 CFR §1.84(a)(2)(iii), an amendment to the specification is hereby submitted to insert the following language as paragraph **[0004]** of the brief description of the drawings:

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

In addition, the specification has been amended to include reference to new Figure 11 as paragraph **[0013]**, and both clean and marked up versions of a substitute specification are submitted herewith.

CONCLUSION

The Examiner is respectfully requested to contact the undersigned by telephone if it is believed that such contact would further the examination of the present application.

Pursuant to 37 C.F.R. 1.136(a)(3), the Applicant(s) hereby request and authorize the U.S. Patent and Trademark Office to (1) treat any concurrent or future reply that requires a petition for extension of time as incorporating a petition for extension of time for the appropriate length of time and (2) charge all required fees, including extension of time fees and fees under 37 C.F.R. 1.16 and 1.17, to Deposit Account No. 50-0393.

Respectfully submitted,

SCHWABE, WILLIAMSON & WYATT, P.C.

October 27, 2020

Date

1211 SW 5th, Ste. 1900
Portland, OR 97204
Telephone: (503) 222-9981
Facsimile: (503) 796-2900

/Justin K. Brask/

Justin K. Brask
Reg. No. 61,080

COPY



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
 United States Patent and Trademark Office
 Address: COMMISSIONER FOR PATENTS
 P.O. Box 1450
 Alexandria, Virginia 22313-1450
 www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC

CONFIRMATION NO. 2637

FORMALITIES LETTER



OC000000117265593

149776

Schwabe Williamson & Wyatt/SunPower
 PACWEST CENTER, SUITE 1900
 1211 SW FIFTH AVENUE
 PORTLAND, OR 97204

Date Mailed: 05/28/2020

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

*Filing Date Granted***Items Required To Avoid Abandonment:**

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A substitute specification in compliance with 37 CFR 1.52, 1.121(b)(3), and 1.125, is required. The substitute specification must be submitted with markings and be accompanied by a clean version (without markings) as set forth in 37 CFR 1.125(c) and a statement that the substitute specification contains no new matter (see 37 CFR 1.125(b)). The specification, claims, and/or abstract page(s) submitted is not acceptable and cannot be scanned or properly stored because:
 - The application papers (including any electronically submitted papers) are not in compliance with 37 CFR 1.52 because pages 15 contain text that is unreadable or of insufficient clarity. Application papers (including any electronically submitted papers) must be presented in a form having sufficient clarity and contrast between the background of the paper and the writing thereon to permit the Office to electronically reproduce the papers by use of digital imaging and optical character recognition. See 37 CFR 1.52(a)(1)(v).

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

- The statutory basic filing fee is missing.

COPY

- The application search fee must be submitted.
- The application examination fee must be submitted.
- Surcharge as set forth in 37 CFR 1.16(f) must be submitted.

The surcharge is due for any one of:

- late submission of the basic filing fee, search fee, or examination fee,
- late submission of inventor's oath or declaration,
- filing an application that does not contain at least one claim on filing, or
- submission of an application filed by reference to a previously filed application.

SUMMARY OF FEES DUE:

The fee(s) required within **TWO MONTHS** from the date of this Notice to avoid abandonment is/are itemized below. No entity status discount is in effect. If applicant is qualified for small entity status, a written assertion of small entity status must be submitted to establish small entity status. (See 37 CFR 1.27). If applicant is qualified for micro entity status, an acceptable Certification of Micro Entity Status must be submitted to establish micro entity status. (See 37 CFR 1.29 and forms PTO/SB/15A and 15B.)

- \$ **300** basic filing fee.
- \$ **160** surcharge.
- \$ **660** search fee.
- \$ **760** examination fee.
- \$(**0**) previous unapplied payment amount.
- \$ **1880** TOTAL FEE BALANCE DUE.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

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Commissioner for Patents
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Alexandria VA 22313-1450

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<https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html>

For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at <http://www.uspto.gov/ebc>.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth 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.

/dmnguyen/

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Smith, et al.

Application No.: 16/877,255

Filed: May 18, 2020

For: SOLAR CELLS WITH IMPROVED
LIFETIME, PASSIVATION AND/OR
EFFICIENCY

Examiner: Unassigned

Art Unit: 1757

Confirmation No.: 2637

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

AMENDMENT UNDER 37 CFR §1.84(a)(2)

Dear Examiner:

This is in reply to the Notice to File Missing Parts of Nonprovisional Application
mailed May 28, 2020. Applicants respectfully request the Examiner to enter this
Amendment and consider the following remarks.

Amendments to the Specification begin on page 2 of this paper.

Remarks/Arguments begin on page 6 of this paper.

Amendments to the Specification:

Please insert the following language after the heading “BRIEF DESCRIPTION OF THE DRAWINGS” on page 2 of the specification as paragraph [0004]:

[0004] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

Please add the following description of new Figure 11 as paragraph [0013] on page 2 of the specification:

[0013] Figure 11 illustrates example processes for solar cell fabrication.

Please delete “Table 1. Example Processes for Solar Cell Fabrication” from page 14 of the specification. Table 1 is submitted concurrently herewith as new Fig. 11 in accordance with 37 CFR §1.84(a)(2)(ii). No new matter has been introduced.

Please replace paragraph [0057] of the specification with the following amended paragraph:

[0057] Turning now to ~~Table 1~~ Figure 11, a table is shown listing Temperature and Surface Dopant Concentration and output results, such as Gettering Location, Surface Passivation, Lifetime and Efficiency, for example processes of fabricating solar cells.

Please replace paragraph [0058] of the specification with the following amended paragraph:

[0058] The method of Figures 1-4 is exemplified in Example Process C of ~~Table 4~~ Figure 11, where a surface, or a portion near the surface, of a silicon substrate was doped at approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process C heated to a temperature above 900 degrees Celsius. The results from Example Process C are gettering in a polysilicon region of the silicon substrate, improved surface passivation at approximately 5 fA/cm^2 , improved lifetime, e.g. typical of approximately $10 \text{ } \mu\text{sec}$, and a $> 0.5 \%$ efficiency increase as compared to other solar cells, e.g. referenced as the baseline efficiency.

Please replace paragraph [0063] of the specification with the following amended paragraph:

[0063] With reference to Figures 8-10, example surface passivation, 1/lifetime and efficiency measurements, respectively, for solar cells fabricated using the methods of the Example Processes A and C of ~~Table 4~~ Figure 11 is shown. The results from Figures 8-10 show that the surface passivation, lifetime and efficiency of solar cells fabricated using the method of Figures 1-4, e.g., Example Process C, have improved surface passivation, lifetime and higher efficiency measurements as compared to the solar cells of Example process A.

Please replace paragraph [0064] of the specification with the following amended paragraph:

[0064] Figure 8 illustrates a graph of surface passivation measurements from solar cells fabricated using the Example Process A and C from ~~Table 1~~ Figure 11. As shown, the Example Process C has lower passivation results as compared to Example Process A. Lower surface passivation is preferred for high efficiency solar cells. Thus, the Example Process C has improved surface passivation results as compared to Example Process A.

Please replace paragraph **[0065]** of the specification with the following amended paragraph:

[0065] With reference to Figure 9, there is shown a graph of 1/lifetime measurements from solar cells fabricated using the Example Process A and C from ~~Table 1~~ Figure 11. As shown, the Example Process C has higher lifetime, lower 1/lifetime results, as compared to Example Process A. Higher lifetime is preferred for high efficiency solar cells. Thus, the Example Process C has improved lifetime results as compared to Example Process A.

Please replace paragraph **[0066]** of the specification with the following amended paragraph:

[0066] Figure 10 illustrates a graph of efficiency measurements from solar cells fabricated using the Example Process A and C from ~~Table 1~~ Figure 11. As shown, the Example Process C has higher efficiency results as compared to Example Process A. Higher solar cell efficiency conversion is preferred to maximize the electricity conversion

from collected light. Thus, the Example Process C has improved efficiency results over Example Process A.

REMARKS

The following remarks are provided in response to the Notice to File Missing Parts of Nonprovisional Application mailed May 28, 2020. Applicants hereby submit a petition to accept color drawings in this application. The color drawings are necessary as the only practical medium by which aspects of the claimed subject matter may be accurately conveyed.

In accordance with 37 CFR §1.84(a)(2)(i), the fee set forth in §1.17(h) is being submitted herewith.

In accordance with 37 CFR §1.84(a)(2)(ii), one set of color drawings is submitted since they are being filed electronically via EFS Web. No new matter has been introduced.

In accordance with 37 CFR §1.84(a)(2)(iii), amendments to the specification are hereby submitted, along with clean and marked versions of a substitute specification.

In response to the Notice to File Missing Parts of Nonprovisional Application, the basic filing fee, search fee, examination fee and surcharge fee, along with appropriate extension of time fees are being submitted herewith.

CONCLUSION

The Examiner is respectfully requested to contact the undersigned by telephone if it is believed that such contact would further the examination of the present application.

Pursuant to 37 C.F.R. 1.136(a)(3), the Applicant(s) hereby request and authorize the U.S. Patent and Trademark Office to (1) treat any concurrent or future reply that requires a petition for extension of time as incorporating a petition for extension of time for the appropriate length of time and (2) charge all required fees, including extension of time fees and fees under 37 C.F.R. 1.16 and 1.17, to Deposit Account No. 50-0393.

Respectfully submitted,

SCHWABE, WILLIAMSON & WYATT, P.C.

October 27, 2020

Date

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Facsimile: (503) 796-2900

/Justin K. Brask/

Justin K. Brask
Reg. No. 61,080

Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(Use as many sheets as necessary)</i>	<i>Complete if Known</i>	
	Application Number	16/877,255
	Filing Date	May 18, 2020
	First Named Inventor	Smith, David D.
	Group Art Unit	1757
	Examiner Name	Unassigned
Sheet 1 of 2		Attorney Docket No: 131815-255190_P167C2DC

US PATENT DOCUMENTS					
Examiner Initial *	Cite No ¹	USP Document Number	Publication or Issue Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 7,718,888	05-18-2016	Cousins	
		US 7,737,357	06-15-2010	Cousins	
		US 8,815,631	08-26-2014	Cousins	
		US 9,269,839	02-23-2016	Lee, et al.	
		US 9,362,426	06-07-2016	Goto, et al.	
		US 9,520,507	12-13-2016	Smith, et al.	
		US-2008/0197454	08-21-2008	Rakotoniana, et al.	
		US-2008/0217747	09-11-2008	Chudzik, et al.	
		US-2010/0084009	04-08-2010	Carlson et al.	
		US-2010/0105190	04-29-2010	Ferre I Tomas	
		US-2010/0139763	06-10-2010	Van Nieuwenhuysen, et al.	
		US-2010/0304527	12-02-2010	Borden, et al.	
		US-2012/0305060	12-06-2012	Fu et al.	
		US-2013/0247965	09-26-2013	Swanson, et al.	
		US-2013/0247981	09-26-2013	Yelundur et al.	
		US-2014/0061531	03-06-2014	Faur, et al.	
		US-2014/0166086	06-19-2014	Marshall	
		US-2014/0166089	06-19-2014	Shepherd, et al.	
		US 2014/0166095	06-19-2014	Loscutoff et al.	
		US-2015/0162483	06-11-2015	Weidman, et al.	
		US-2016/0056322	02-25-2016	Yang, et al.	
		US-2016/0126368	05-05-2016	Lee, et al.	
		US-2016/0155866	06-02-2016	Ha, et al.	
		US-2016/0155877	06-02-2016	Chung, et al.	
		US-2016/0155885	06-02-2016	Shim, et al.	
		US-2016/0181461	06-23-2016	Ueyama, et al.	
		US-2016/0197210	07-07-2016	Hayashi, et al.	
		US-2016/0240704	08-18-2016	Shim	
		US-2016/0240705	08-18-2016	Takahama	
		US-2016/0268454	09-15-2016	Gwon	

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No ¹	Foreign Patent Document Country Code/Number/Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ²
	15	JP 2011-166021 A	08-25-2011	Shin-Etsu Chemical Co Ltd		
	16	CN 102694077	09-26-2012	Lin, et al.		

EXAMINER

DATE CONSIDERED

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449)
 * 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. † Applicant's unique citation designation number (optional) ‡ Applicant is to place a check mark here if English language Translation is attached

Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(Use as many sheets as necessary)</i>	<i>Complete if Known</i>	
	Application Number	16/877,255
	Filing Date	May 18, 2020
	First Named Inventor	Smith, David D.
	Group Art Unit	1757
	Examiner Name	Unassigned
Sheet 2 of 2	Attorney Docket No: 131815-255190_P167C2DC	

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No. ¹	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 ²
	1	Pre-Interview Office Action for U.S. Patent Application No. 14/579,935 (Attorney Docket No. 131815-228875_P167) mailed January 11, 2016, 4 pgs.	
	2	International Search Report and Written Opinion from PCT/US2015/067220 (Attorney Docket No. 7923.P167PCT) mailed April 29, 2016, 13 pgs.	
	3	First Action Interview Pre-Interview Communication from U.S. Patent Application No. 15/213,273 mailed March 7, 2017, 7 pgs.	
	4	First Action Interview Office Action Summary from U.S. Patent Application No. 15/213,273 mailed May 23, 2017, 6 pgs.	
	5	International Preliminary Report on Patentability from PCT/US2015/067220 (Attorney Docket No. 131815-228879_P167PCT) mailed July 6, 2017, 11 pgs.	
	6	Extended European Search Report from European Patent Application No. 15874267.6 (Attorney Docket No. 131815-228878_P167EP) mailed March 9, 2018, 15 pgs.	
	7	Jan Bultman, et al. "Methods of emitter formation for crystalline silicon solar cells," 31 May 2010 (2010-05-31), XP055026905, Retrieved from the Internet, www.pv-tech.org, April 10, 2018, 12 pgs.	
	8	First Office Action for Chinese Application No. 2015800700209 (Attorney Docket No. 131815-228877_P167CN), issued August 31, 2018, 14 pgs.	
	9	First Action Interview Pre-Interview Communication from U.S. Patent Application No. 16/228,165 (Attorney Docket No. 131915-244905_P167C2D) dated April 8, 2019, 6 pgs.	
	10	Second Office Action from Chinese Patent Application No. 2015800700209 (Attorney Docket No. S1117CN_P167CN) mailed April 19, 2019, 12 pgs.	
	11	Examination Report from European Patent Application No. 15874267.6 (Attorney Docket No. P167EP_S1117EP) mailed April 30, 2019, 6 pgs.	
	12	First Action Interview from U.S. Patent Application No. 16/228,165 (Attorney Docket No. 131815-244905_P167C2D) dated July 12, 2019, 5 pgs.	
	13	Rejection Decision from Chinese Patent Application No. 2015800700209 (Attorney Docket No. S1117-CN) dated October 28, 2019, 9 pgs.	
	14	Reexamination Notice from Chinese Patent Application No. 2015800700209 (Attorney Docket No. S1117-CN) dated July 3, 2020, 12 pgs.	

EXAMINER

DATE CONSIDERED

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449)
 *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. † Applicant's unique citation designation number (optional) ‡ Applicant is to place a check mark here if English language Translation is attached

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application No.	16/877,255
Filing Date	May 18, 2020
First Inventor	Smith, David D.
Art Unit	1757
Examiner Name	Unassigned
Attorney Docket No.	131815-255190_P167C2DC
Conf. No.	2637

DUTY OF DISCLOSURE STATEMENT

In accordance with the duty of disclosure, enclosed is a copy of an Information Disclosure Statement (IDS) Citation Form PTO/SB/08 or PTO-1449, together with copies of the documents cited on that form, except for copies not required to be submitted (e.g., copies of U.S. patents and U.S. published patent applications need not be enclosed). It is respectfully requested that the cited references be considered and that the enclosed copy of PTO/SB/08 be initiated by the Examiner to indicate such consideration and a copy thereof returned to applicant(s).

The submission of this Information Disclosure Statement is not to be construed as a representation that a search has been made in the subject application and is not to be construed as an admission that the information cited in this statement is material to patentability.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

- ☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).
- OR**
- ☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).
- OR**
- ☒ None
- ☐ The IDS Filing Fee in the amount of \$260.00 as set forth in 37 CFR 1.17(p) has been submitted herewith.
- ☒ It is requested that any requisite fees be debited from Deposit Account 50-0393.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of signature.

Signature	/Justin K. Brask/	Date (MM-DD-YYYY)	10-27-2020
Name/Print	Justin K. Brask	Registration Number	61,080

I hereby certify that this correspondence is being submitted electronically via EFS Web on the date shown below.

Gigi Hoover /Gigi Hoover/

Date 10-27-2020

This collection of information is required by 37 CFR 1.97 and 1.98. 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 1 hour 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 or 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.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 7923P167PCT	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/US2015/067220	International filing date (<i>day/month/year</i>) 21 December 2015 (21.12.2015)	(Earliest) Priority Date (<i>day/month/year</i>) 22 December 2014 (22.12.2014)
Applicant SUNPOWER CORPORATION		

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of :

☒ the international application in the language in which it was filed

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (See Box No. II)

3. ☐ **Unity of invention is lacking** (See Box No. III)

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 1

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/067220**A. CLASSIFICATION OF SUBJECT MATTER****H01L 31/04(2006.01)i, H01L 31/0224(2006.01)i, H01L 31/0368(2006.01)i, H01L 31/14(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 31/04; H01L 21/322; H01L 21/469; H01L 31/0224; H01L 31/18; H01L 29/30; H01L 31/0232; H01L 23/58; H01L 31/0368; H01L 31/14

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & keywords: solar cell, metal impurity, dielectric, emitter, metal contact, heat, getter contaminants, and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2011-166021 A (SHIN-ETSU CHEMICAL CO., LTD.) 25 August 2011 See paragraphs [0001]-[0004], [0009]-[0032], and [0048]; claim 1; and figures 1-3.	1-20
Y	US 2012-0305060 A1 (JIANMING FU et al.) 06 December 2012 See paragraphs [0030]-[0056]; claims 1 and 3; and figures 1-4.	1-20
Y	US 2014-0166095 A1 (PAUL LOSCUTOFF et al.) 19 June 2014 See paragraphs [0012]-[0033]; claim 7; and figures 1-13.	10-11
A	US 2010-0105190 A1 (RAFEL FERRE I TOMAS) 29 April 2010 See paragraphs [0023]-[0030]; claims 1-5; and figures 1a-1c.	1-20
A	US 2008-0197454 A1 (JEAN PATRICE RAKOTONIANA et al.) 21 August 2008 See paragraphs [0034]-[0043]; claims 1 and 10; and figures 6-8.	1-20
A	US 2008-0217747 A1 (MICHAEL P. CHUDZIK et al.) 11 September 2008 See paragraphs [0024]-[0059] and figures 1A-2B.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

29 April 2016 (29.04.2016)

Date of mailing of the international search report

29 April 2016 (29.04.2016)

Name and mailing address of the ISA/KR

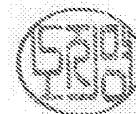
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

NHO, Ji Myong

Telephone No. +82-42-481-8528



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/067220

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2011-166021 A	25/08/2011	JP 5338702 B2	13/11/2013
US 2012-0305060 A1	06/12/2012	CN 103650165 A	19/03/2014
		EP 2715802 A2	09/04/2014
		EP 2715802 A4	10/12/2014
		US 2015-0236177 A1	20/08/2015
		US 9054256 B2	09/06/2015
		WO 2012-166974 A2	06/12/2012
		WO 2012-166974 A3	18/04/2013
US 2014-0166095 A1	19/06/2014	AU 2013-362916 A1	18/06/2015
		CN 104885232 A	02/09/2015
		EP 2936570 A1	28/10/2015
		KR 10-2015-0097647 A	26/08/2015
		SG 11201504664 A	30/07/2015
		TW 201432923 A	16/08/2014
		WO 2014-100004 A1	26/06/2014
US 2010-0105190 A1	29/04/2010	CN 102197497 A	21/09/2011
		EP 2180531 A1	28/04/2010
		JP 2012-506629 A	15/03/2012
		KR 10-2011-0086833 A	01/08/2011
		TW 201030854 A	16/08/2010
		US 8124502 B2	28/02/2012
		WO 2010-046284 A1	29/04/2010
US 2008-0197454 A1	21/08/2008	EP 2168149 A1	31/03/2010
		EP 2168149 A4	28/12/2011
		EP 2168149 B1	19/06/2013
		WO 2008-101144 A1	21/08/2008
US 2008-0217747 A1	11/09/2008	CN 101361173 A	04/02/2009
		EP 1974372 A2	01/10/2008
		EP 1974372 A4	09/12/2009
		JP 2009-524239 A	25/06/2009
		JP 5336857 B2	06/11/2013
		KR 10-1144436 B1	15/05/2012
		KR 10-2008-0094894 A	27/10/2008
		US 2007-0173008 A1	26/07/2007
		US 7425497 B2	16/09/2008
		US 7750418 B2	06/07/2010
		WO 2007-087127 A2	02/08/2007
		WO 2007-087127 A3	22/11/2007

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
VINCENT, LESTER J.

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP 1279
OAKMEAD PARKWAY SUNNYVALE CA 94085 USA

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing
(day/month/year) **29 April 2016 (29.04.2016)**

Applicant's or agent's file reference
7923P167PCT

FOR FURTHER ACTION

See paragraph 2 below

International application No.
PCT/US2015/067220

International filing date (day/month/year)
21 December 2015 (21.12.2015)

Priority date(day/month/year)
22 December 2014 (22.12.2014)

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

H01L 31/04(2006.01)i, H01L 31/0224(2006.01)i, H01L 31/0368(2006.01)i, H01L 31/14(2006.01)i

Applicant
SUNPOWER CORPORATION

1. This opinion contains indications relating to the following items:

- | | | |
|-------------------------------------|--------------|---|
| ☒ | Box No. I | Basis of the opinion |
| ☐ | Box No. II | Priority |
| ☐ | Box No. III | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability |
| ☐ | Box No. IV | Lack of unity of invention |
| ☒ | Box No. V | Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement |
| ☐ | Box No. VI | Certain documents cited |
| ☐ | Box No. VII | Certain defects in the international application |
| ☒ | Box No. VIII | Certain observations on the international application |

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon,
35208, Republic of Korea
Facsimile No. +82-42-481-8578



Date of completion of this opinion

29 April 2016 (29.04.2016)

Authorized officer

NHO, Ji Myong

Telephone No. +82-42-481-8528



**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2015/067220

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :
- ☒ the international application in the language in which it was filed
 - ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:
- a. ☐ forming part of the international application as filed:
 - ☐ in the form of an Annex C/ST.25 text file.
 - ☐ on paper or in the form of an image file.
 - b. ☐ furnished together with the international application under PCT Rule 13ter.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
 - c. ☐ furnished subsequent to the international filing date for the purposes of international search only:
 - ☐ in the form of an Annex C/ST.25 text file (Rule 13ter.1(a)).
 - ☐ on paper or in the form of an image file (Rule 13ter.1(b) and Administrative Instructions, Section 713).
4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/US2015/067220

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: JP 2011-166021 A (SHIN-ETSU CHEMICAL CO., LTD.) 25 August 2011

D2: US 2012-0305060 A1 (JIANMING FU et al.) 06 December 2012

D3: US 2014-0166095 A1 (PAUL LOSCUTOFF et al.) 19 June 2014

2.1 Novelty and Inventive Step

2.1.1 Concerning Claims 1-8

D1, which is considered to be the closest prior art to the subject matter of claims 1-8, discloses a solar cell comprising:

a p-type silicon substrate 1 (see paragraphs [0003] and [0048]; and figure 1);

an n-type impurity diffusion layer 2 disposed over the substrate, the diffusion layer having a metal impurity by high temperature heat treatment and forming in a single emitter structure (see paragraphs [0003], [0020], and [0025]; and figure 1); and

an electrode 7 electrically connected to the impurity diffusion layer (see paragraphs [0003], [0009], and [0048]; and figure 1).

2.1.1.1 Independent Claim 1

Claim 1 differs from D1 in that a solar cell of claim 1 comprises a dielectric region over a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$. However, the difference can be easily derived from the feature of D2 in analogous art (a quantum-tunneling-barrier layer (dielectric material is deposited) situated above a base layer (SG-Si substrate 200), wherein a doping concentration of the base layer 304 can be between $1 \times 10^{15} / \text{cm}^3$ and $1 \times 10^{17} / \text{cm}^3$ (see paragraphs [0034] and [0046]; claim 1 and figure 2B)). Accordingly, it would be obvious to a person skilled in the art to combine the disclosures of D1 and D2, thereby arriving at the claim 1. Therefore, claim 1 is novel under PCT Article 33(2), but lacks an inventive step under PCT Article 33(3).

Continued on Supplemental Box

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/US2015/067220

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claim 8 is worded in reference to 'the second emitter region' of claim 5. However, said 'second emitter region' has not been previously worded in claim 5. Therefore, claim 8 does not meet the requirement of PCT Article 6.

(NOTE : Referring to the description, it is understood that claim 8 is dependent on claim 6. Accordingly, this written opinion has been established on the assumption that claim 8 refers to claim 6.)

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of : Box No. V

2.1.1.2 Dependent Claims 2-8

Claims 2-8 are directly or indirectly dependent on claim 1.

The additional features of **claims 2 and 3** can be easily derived from the features of D2 (emitter layer 206 is situated on the front side of the solar cell facing the incident sunlight (see paragraph [0035]); it is also possible to fabricate tunneling junction solar cells with an emitter layer situated on the backside of the solar cell (see paragraph [0053]); and a front-side electrode and a back-side electrode (see claim 1)).

The additional feature of **claim 4** can be easily derived from the feature of D2 (the doping concentration of base layer 304 can be between $1 \times 10^{15}/\text{cm}^3$ and $1 \times 10^{17}/\text{cm}^3$ (see paragraph [0046])).

The additional feature of **claim 5** is merely a matter of design option in view of the feature of D2 (the emitter layer comprises at least one of amorphous-Si (a-Si) and amorphous-SiC (a-SiC) (see claim 3)).

The additional features of **claims 6-8** are merely matters of design option in view of the features of D2 (emitter layer 206 is situated on the front side of the solar cell facing the incident sunlight (see paragraph [0035]); it is also possible to fabricate tunneling junction solar cells with an emitter layer situated on the backside of the solar cell (see paragraph [0053]); and a front-side electrode and a back-side electrode (see claim 1)).

Accordingly, claims 2-8 would have been obvious to a person skilled in the art over D1 in view of D2. Therefore, claims 2-8 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.1.2 Concerning Claims 9-15

D1, which is considered to be the closest prior art to the subject matter of claims 9-15, discloses a method comprising:

forming a p-type silicon substrate 1 (see paragraphs [0003] and [0048]; and figure 1); and
forming n-type impurity diffusion layer 2 in a single emitter structure over the substrate, the diffusion layer having a metal impurity by high temperature heat treatment, wherein the high temperature heat treatment is 800-1050 °C (see paragraphs [0019]-[0020] and [0025]; and figure 1).

Continued on The Next Page

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of : Previous Page

2.1.2.1 Independent Claim 9

Claim 9 differs from D1 in that the method of claim 9 comprises the steps of: forming a dielectric region on a silicon substrate; and forming a dopant region on a surface of the silicon substrate. However, the differences can be easily derived from the feature of D2 in analogous art (a quantum-tunneling-barrier layer (dielectric material is deposited) situated above a base layer (SG-Si substrate 200), wherein a doping concentration of the base layer 304 can be between $1 \times 10^{15}/\text{cm}^3$ and $1 \times 10^{17}/\text{cm}^3$ (see paragraphs [0034] and [0046]; claim 1; and figure 2B)). Accordingly, it would be obvious to a person skilled in the art to combine the disclosures of D1 and D2 to arrive at claim 9. Therefore, claim 9 is novel under PCT Article 33(2), but lacks an inventive step under PCT Article 33(3).

2.1.2.2 Dependent Claims 10-11

Claims 10-11 are directly or indirectly dependent on claim 9.

The additional features of **claims 10 and 11** are not explicitly disclosed in D1 and D2. However, the features are merely matters of design option in view of D3 in analogous art (forming a first emitter on the thin dielectric layer on a backside of the solar cell (see claim 7); forming a second emitter in the single crystalline silicon substrate on the backside the solar cell (see claim 7); and forming a first metal contact connected to the first emitter and a second metal contact connected to the second emitter on the backside of the solar cell (see claim 7)).

Accordingly, claims 10-11 would have been obvious to a person skilled in the art over D1 and D2 in view of D3. Therefore, claims 10-11 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.1.2.3 Dependent Claims 12-15

Claims 12-15 are directly or indirectly dependent on claim 9.

The additional features of **claims 12 and 13** can be easily derived from the feature of D1 (heating at 200 °C for 10 minutes to form n-type diffusion layer (see paragraph [0032])).

The additional feature of **claim 14** is merely a matter of design option in view of the feature of D2 (the emitter layer comprises at least one of amorphous-Si (a-Si) and amorphous-SiC (a-SiC) (see claim 3)).

Continued on The Next Page

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of : Previous Page

The additional feature of **claim 15** can be easily derived from the feature of D2 (an n-type doped (using phosphorous) SG-Si wafer is selected (see paragraphs [0031] and [0036])).

Accordingly, claims 12-15 would have been obvious to a person skilled in the art over D1 in view of D2. Therefore, claims 12-15 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.1.3 Concerning Claims 16-20

D1, which is considered to be the closest prior art to the subject matter of claims 16-20, discloses a method comprising:

forming a p-type silicon substrate 1 (see paragraphs [0003] and [0048]; and figure 1); and
forming n-type impurity diffusion layer 2 in a single emitter structure over the substrate, the diffusion layer having a metal impurity by high temperature heat treatment, wherein the high temperature heat treatment is 800-1050 °C (see paragraphs [0019]-[0020] and [0025]; and figure 1).

2.1.3.1 Independent Claim 16

Claim 16 differs from D1 in that the method of claim 16 comprises the steps of: forming a dielectric region on a silicon substrate; forming a second emitter region having metal impurity over the dielectric region on the back side of the solar cell; forming a dopant region on a surface of the silicon substrate; and forming first and second metal contacts over the first and second emitter regions, respectively. However, these features are merely matters of design option in view of D2 in analogous art (a quantum-tunneling-barrier layer (dielectric material is deposited) situated above a base layer (SG-Si substrate 200), wherein a doping concentration of the base layer 304 can be between $1 \times 10^{15}/\text{cm}^3$ and $1 \times 10^{17}/\text{cm}^3$ (see paragraphs [0034] and [0046]; claim 1 and figure 2B); emitter layer 206 is situated on the front side of the solar cell facing the incident sunlight (see paragraph [0035]); it is also possible to fabricate tunneling junction solar cells with an emitter layer situated on the backside of the solar cell (see paragraph [0053]); and a front-side electrode and a back-side electrode (see claim 1)). Accordingly, it would be obvious to a person skilled in the art to combine the disclosures of D1 and D2 to arrive at claim 16. Therefore, claim 16 is novel under PCT Article 33(2), but lacks an inventive step under PCT Article 33(3).

Continued on The Next Page

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/US2015/067220

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of : Previous Page

2.1.3.2 Dependent Claims 17-20

Claims 17-20 are directly or indirectly dependent on claim 16.

The additional features of **claims 17 and 18** can be easily derived from the feature of D1 (heating at 200 °C for 10 minutes to form a n-type diffusion layer (see paragraph [0032])).

The additional feature of **claim 19** is merely a matter of design option in view of the feature of D2 (the emitter layer comprises at least one of amorphous-Si (a-Si) and amorphous-SiC (a-SiC) (see claim 3)).

The additional feature of **claim 20** can be easily derived from the feature of D2 (an n-type doped (using phosphorous) SG-Si wafer is selected (see paragraphs [0031] and [0036])).

Accordingly, claims 17-20 would have been obvious to a person skilled in the art over D1 in view of D2. Therefore, claims 17-20 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.2 Industrial Applicability

Claims 1-20 are industrially applicable under PCT Article 33(4).



ADVANCE E-MAIL

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING
TRANSMITTAL OF COPY OF INTERNATIONAL
PRELIMINARY REPORT ON PATENTABILITY
(CHAPTER I OF THE PATENT COOPERATION
TREATY)
(PCT Rule 44bis.1(c))

To:

JK9-BV
SunPower
7923P167PCT

VINCENT, Lester J.
Blakely Sokoloff Taylor & Zafman LLP
1279 Oakmead Parkway
Sunnyvale, California 94085
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year)
06 July 2017 (06.07.2017)

Applicant's or agent's file reference
7923P167PCT

IMPORTANT NOTICE

International application No.
PCT/US2015/067220

International filing date (day/month/year)
21 December 2015 (21.12.2015)

Priority date (day/month/year)
22 December 2014 (22.12.2014)

Applicant

SUNPOWER CORPORATION

The International Bureau transmits herewith a copy of the international preliminary report on patentability (Chapter I of the Patent Cooperation Treaty)

RECEIVED

JUL 12 2017

FIP DEPT.

Previously Docketed
On 7.6.17

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SUNNYVALE

JUL 12 2017

BLAKELY SOKOLOFF
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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44bis)

Applicant's or agent's file reference 7923P167PCT	FOR FURTHER ACTION	See item 4 below
International application No. PCT/US2015/067220	International filing date (<i>day/month/year</i>) 21 December 2015 (21.12.2015)	Priority date (<i>day/month/year</i>) 22 December 2014 (22.12.2014)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant SUNPOWER CORPORATION		

1.	This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 bis.1(a).																									
2.	This REPORT consists of a total of 9 sheets, including this cover sheet. In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.																									
3.	This report contains indications relating to the following items: <table border="0"><tr><td>☒</td><td>Box No. I</td><td>Basis of the report</td></tr><tr><td>☐</td><td>Box No. II</td><td>Priority</td></tr><tr><td>☐</td><td>Box No. III</td><td>Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td></tr><tr><td>☐</td><td>Box No. IV</td><td>Lack of unity of invention</td></tr><tr><td>☒</td><td>Box No. V</td><td>Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td></tr><tr><td>☐</td><td>Box No. VI</td><td>Certain documents cited</td></tr><tr><td>☐</td><td>Box No. VII</td><td>Certain defects in the international application</td></tr><tr><td>☒</td><td>Box No. VIII</td><td>Certain observations on the international application</td></tr></table>		☒	Box No. I	Basis of the report	☐	Box No. II	Priority	☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability	☐	Box No. IV	Lack of unity of invention	☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement	☐	Box No. VI	Certain documents cited	☐	Box No. VII	Certain defects in the international application	☒	Box No. VIII	Certain observations on the international application
☒	Box No. I	Basis of the report																								
☐	Box No. II	Priority																								
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☐	Box No. IV	Lack of unity of invention																								
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement																								
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☐	Box No. VII	Certain defects in the international application																								
☒	Box No. VIII	Certain observations on the international application																								
4.	The International Bureau will communicate this report to designated Offices in accordance with Rules 44bis.3(c) and 93bis.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44bis .2).																									

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 82 70	Date of issuance of this report 27 June 2017 (27.06.2017) Authorized officer Agnès Wittmann-Regis e-mail: pct.team6@wipo.int
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Form PCT/IB/373 (January 2004)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
VINCENT, LESTER J.

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP 1279
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PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing
(day/month/year) **29 April 2016 (29.04.2016)**

Applicant's or agent's file reference
7923P167PCT

FOR FURTHER ACTION

See paragraph 2 below

International application No.
PCT/US2015/067220

International filing date (day/month/year)
21 December 2015 (21.12.2015)

Priority date(day/month/year)
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International Patent Classification (IPC) or both national classification and IPC

H01L 31/04(2006.01)i, H01L 31/0224(2006.01)i, H01L 31/0368(2006.01)i, H01L 31/14(2006.01)i

Applicant
SUNPOWER CORPORATION

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

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29 April 2016 (29.04.2016)

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**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

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Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :
 - ☒ the international application in the language in which it was filed
 - ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:
 - a. ☐ forming part of the international application as filed:
 - ☐ in the form of an Annex C/ST.25 text file.
 - ☐ on paper or in the form of an image file.
 - b. ☐ furnished together with the international application under PCT Rule 13ter.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
 - c. ☐ furnished subsequent to the international filing date for the purposes of international search only:
 - ☐ in the form of an Annex C/ST.25 text file (Rule 13ter.1(a)).
 - ☐ on paper or in the form of an image file (Rule 13ter.1(b) and Administrative Instructions, Section 713).
4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

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Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-20	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: JP 2011-166021 A (SHIN-ETSU CHEMICAL CO., LTD.) 25 August 2011

D2: US 2012-0305060 A1 (JIANMING FU et al.) 06 December 2012

D3: US 2014-0166095 A1 (PAUL LOSCUTOFF et al.) 19 June 2014

2.1 Novelty and Inventive Step

2.1.1 Concerning Claims 1-8

D1, which is considered to be the closest prior art to the subject matter of claims 1-8, discloses a solar cell comprising:

a p-type silicon substrate 1 (see paragraphs [0003] and [0048]; and figure 1);

an n-type impurity diffusion layer 2 disposed over the substrate, the diffusion layer having a metal impurity by high temperature heat treatment and forming in a single emitter structure (see paragraphs [0003], [0020], and [0025]; and figure 1); and

an electrode 7 electrically connected to the impurity diffusion layer (see paragraphs [0003], [0009], and [0048]; and figure 1).

2.1.1.1 Independent Claim 1

Claim 1 differs from D1 in that a solar cell of claim 1 comprises a dielectric region over a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$. However, the difference can be easily derived from the feature of D2 in analogous art (a quantum-tunneling-barrier layer (dielectric material is deposited) situated above a base layer (SG-Si substrate 200), wherein a doping concentration of the base layer 304 can be between $1 \times 10^{15} / \text{cm}^3$ and $1 \times 10^{17} / \text{cm}^3$ (see paragraphs [0034] and [0046]; claim 1 and figure 2B)). Accordingly, it would be obvious to a person skilled in the art to combine the disclosures of D1 and D2, thereby arriving at the claim 1. Therefore, claim 1 is novel under PCT Article 33(2), but lacks an inventive step under PCT Article 33(3).

Continued on Supplemental Box



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Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claim 8 is worded in reference to 'the second emitter region' of claim 5. However, said 'second emitter region' has not been previously worded in claim 5. Therefore, claim 8 does not meet the requirement of PCT Article 6.

(NOTE : Referring to the description, it is understood that claim 8 is dependent on claim 6. Accordingly, this written opinion has been established on the assumption that claim 8 refers to claim 6.)

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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of : Box No. V

2.1.1.2 Dependent Claims 2-8

Claims 2-8 are directly or indirectly dependent on claim 1.

The additional features of **claims 2 and 3** can be easily derived from the features of D2 (emitter layer 206 is situated on the front side of the solar cell facing the incident sunlight (see paragraph [0035]); it is also possible to fabricate tunneling junction solar cells with an emitter layer situated on the backside of the solar cell (see paragraph [0053]); and a front-side electrode and a back-side electrode (see claim 1)).

The additional feature of **claim 4** can be easily derived from the feature of D2 (the doping concentration of base layer 304 can be between $1 \times 10^{15}/\text{cm}^3$ and $1 \times 10^{17}/\text{cm}^3$ (see paragraph [0046])).

The additional feature of **claim 5** is merely a matter of design option in view of the feature of D2 (the emitter layer comprises at least one of amorphous-Si (a-Si) and amorphous-SiC (a-SiC) (see claim 3)).

The additional features of **claims 6-8** are merely matters of design option in view of the features of D2 (emitter layer 206 is situated on the front side of the solar cell facing the incident sunlight (see paragraph [0035]); it is also possible to fabricate tunneling junction solar cells with an emitter layer situated on the backside of the solar cell (see paragraph [0053]); and a front-side electrode and a back-side electrode (see claim 1)).

Accordingly, claims 2-8 would have been obvious to a person skilled in the art over D1 in view of D2. Therefore, claims 2-8 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.1.2 Concerning Claims 9-15

D1, which is considered to be the closest prior art to the subject matter of claims 9-15, discloses a method comprising:

forming a p-type silicon substrate 1 (see paragraphs [0003] and [0048]; and figure 1); and
forming n-type impurity diffusion layer 2 in a single emitter structure over the substrate, the diffusion layer having a metal impurity by high temperature heat treatment, wherein the high temperature heat treatment is 800-1050 °C (see paragraphs [0019]-[0020] and [0025]; and figure 1).

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2.1.2.1 Independent Claim 9

Claim 9 differs from D1 in that the method of claim 9 comprises the steps of: forming a dielectric region on a silicon substrate; and forming a dopant region on a surface of the silicon substrate. However, the differences can be easily derived from the feature of D2 in analogous art (a quantum-tunneling-barrier layer (dielectric material is deposited) situated above a base layer (SG-Si substrate 200), wherein a doping concentration of the base layer 304 can be between $1 \times 10^{15}/\text{cm}^3$ and $1 \times 10^{17}/\text{cm}^3$ (see paragraphs [0034] and [0046]; claim 1; and figure 2B)). Accordingly, it would be obvious to a person skilled in the art to combine the disclosures of D1 and D2 to arrive at claim 9. Therefore, claim 9 is novel under PCT Article 33(2), but lacks an inventive step under PCT Article 33(3).

2.1.2.2 Dependent Claims 10-11

Claims 10-11 are directly or indirectly dependent on claim 9.

The additional features of **claims 10 and 11** are not explicitly disclosed in D1 and D2. However, the features are merely matters of design option in view of D3 in analogous art (forming a first emitter on the thin dielectric layer on a backside of the solar cell (see claim 7); forming a second emitter in the single crystalline silicon substrate on the backside the solar cell (see claim 7); and forming a first metal contact connected to the first emitter and a second metal contact connected to the second emitter on the backside of the solar cell (see claim 7)).

Accordingly, claims 10-11 would have been obvious to a person skilled in the art over D1 and D2 in view of D3. Therefore, claims 10-11 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.1.2.3 Dependent Claims 12-15

Claims 12-15 are directly or indirectly dependent on claim 9.

The additional features of **claims 12 and 13** can be easily derived from the feature of D1 (heating at 200 °C for 10 minutes to form n-type diffusion layer (see paragraph [0032])).

The additional feature of **claim 14** is merely a matter of design option in view of the feature of D2 (the emitter layer comprises at least one of amorphous-Si (a-Si) and amorphous-SiC (a-SiC) (see claim 3)).

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The additional feature of **claim 15** can be easily derived from the feature of D2 (an n-type doped (using phosphorous) SG-Si wafer is selected (see paragraphs [0031] and [0036])).

Accordingly, claims 12-15 would have been obvious to a person skilled in the art over D1 in view of D2. Therefore, claims 12-15 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.1.3 Concerning Claims 16-20

D1, which is considered to be the closest prior art to the subject matter of claims 16-20, discloses a method comprising:

forming a p-type silicon substrate 1 (see paragraphs [0003] and [0048]; and figure 1); and
forming n-type impurity diffusion layer 2 in a single emitter structure over the substrate, the diffusion layer having a metal impurity by high temperature heat treatment, wherein the high temperature heat treatment is 800-1050 °C (see paragraphs [0019]-[0020] and [0025]; and figure 1).

2.1.3.1 Independent Claim 16

Claim 16 differs from D1 in that the method of claim 16 comprises the steps of: forming a dielectric region on a silicon substrate; forming a second emitter region having metal impurity over the dielectric region on the back side of the solar cell; forming a dopant region on a surface of the silicon substrate; and forming first and second metal contacts over the first and second emitter regions, respectively. However, these features are merely matters of design option in view of D2 in analogous art (a quantum-tunneling-barrier layer (dielectric material is deposited) situated above a base layer (SG-Si substrate 200), wherein a doping concentration of the base layer 304 can be between $1 \times 10^{15}/\text{cm}^3$ and $1 \times 10^{17}/\text{cm}^3$ (see paragraphs [0034] and [0046]; claim 1 and figure 2B); emitter layer 206 is situated on the front side of the solar cell facing the incident sunlight (see paragraph [0035]); it is also possible to fabricate tunneling junction solar cells with an emitter layer situated on the backside of the solar cell (see paragraph [0053]); and a front-side electrode and a back-side electrode (see claim 1)). Accordingly, it would be obvious to a person skilled in the art to combine the disclosures of D1 and D2 to arrive at claim 16. Therefore, claim 16 is novel under PCT Article 33(2), but lacks an inventive step under PCT Article 33(3).

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2.1.3.2 Dependent Claims 17-20

Claims 17-20 are directly or indirectly dependent on claim 16.

The additional features of **claims 17 and 18** can be easily derived from the feature of D1 (heating at 200 °C for 10 minutes to form a n-type diffusion layer (see paragraph [0032])).

The additional feature of **claim 19** is merely a matter of design option in view of the feature of D2 (the emitter layer comprises at least one of amorphous-Si (a-Si) and amorphous-SiC (a-SiC) (see claim 3)).

The additional feature of **claim 20** can be easily derived from the feature of D2 (an n-type doped (using phosphorous) SG-Si wafer is selected (see paragraphs [0031] and [0036])).

Accordingly, claims 17-20 would have been obvious to a person skilled in the art over D1 in view of D2. Therefore, claims 17-20 are novel under PCT Article 33(2), but lack an inventive step under PCT Article 33(3).

2.2 Industrial Applicability

Claims 1-20 are industrially applicable under PCT Article 33(4).

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(12) 公開特許公報(A)

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最終頁に続く

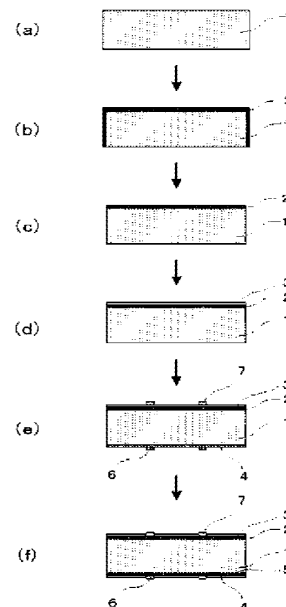
(54) 【発明の名称】 太陽電池の製造方法及び太陽電池

(57) 【要約】 (修正有)

【課題】 少数キャリアパルクライフタイムの高い、高効率な太陽電池を安価に製造できる太陽電池の製造方法及びこの製造方法によって得られる太陽電池を提供する。

【解決手段】 シリコン基板 1 を、この基板とは異なる導電型の不純物存在下で高温熱処理して不純物拡散層 2 を形成した後、この不純物拡散層 2 に電氣的に接続する電極 4, 6, 7 を形成して太陽電池を製造するに際し、上記高温熱処理して不純物拡散層を形成した後、この高温熱処理温度よりも低い温度で、好ましくは高温熱処理炉とは異なる熱処理炉を用いて低温熱処理を行うことで、基板中に存在する鉄や亜鉛等の金属不純物を n 型拡散層 2、P S G (リン珪酸塩) 層等のデバイス不活性な領域内にゲッターリング (捕獲) して、少数キャリアパルクライフタイムの高い基板を作製する。

【選択図】 図 3



【特許請求の範囲】

【請求項 1】

シリコン基板を、これとは異なる導電型の不純物存在下で高温熱処理して該基板表面上記不純物を拡散した不純物拡散層を形成した後、この不純物拡散層に電氣的に接続する電極を形成する工程を含む太陽電池の製造方法であって、上記高温熱処理後、上記高温熱処理温度より低い温度で上記基板を低温熱処理することを特徴とする太陽電池の製造方法。

【請求項 2】

高温熱処理及び低温熱処理を別々の熱処理炉で行う請求項 1 記載の太陽電池の製造方法。

【請求項 3】

低温熱処理温度が、600～800℃である請求項 1 又は 2 記載の太陽電池の製造方法。

【請求項 4】

低温熱処理時間が、15～75 分間である請求項 1 乃至 3 のいずれか 1 項記載の太陽電池の製造方法。

【請求項 5】

高温熱処理及び低温熱処理において、それぞれの処理温度の±50℃以内の温度に保持した熱処理炉内に基板を直接入れて熱処理した後、該基板を上記炉内から直接取り出す請求項 1 乃至 4 のいずれか 1 項記載の太陽電池の製造方法。

【請求項 6】

請求項 1 乃至 5 のいずれか 1 項記載の太陽電池の製造方法により製造されたことを特徴とする太陽電池。

【発明の詳細な説明】

【技術分野】

【0001】

本発明は、太陽電池の製造方法及び太陽電池に関し、さらに詳述すると、リン等の不純物を基板表面に熱拡散させて不純物拡散層を形成して太陽電池を製造する熱処理工程において、不純物拡散層を形成するための高温熱処理後、さらに低温熱処理を行うことで、基板中に存在する金属不純物を、n 型拡散層、PSG (Phospho Silicate Glass、リン珪酸塩) 層等のデバイス不活性な領域内にゲッタリング (捕獲) し、基板の少数キャリアライフタイムを向上させることができる太陽電池の製造方法及び太陽電池に関する。

【背景技術】

【0002】

現在、民生用の太陽電池を製造するにあたって、太陽電池の高効率化及び製造コストの低減が重要課題となっている。一般的には、以下のような工程で太陽電池を製造する方法が広く採用されている。その詳細は例えば次の通りである。

【0003】

まず、図 1 に示すように、チョクラルスキー (CZ) 法により作製した単結晶シリコンインゴットやキャスト法により作製した多結晶シリコンインゴットをマルチワイヤー法でスライスすることにより得られた p 型シリコン基板 1 を用意する。次に、アルカリ溶液で基板表面のスライスによるダメージを取り除いた後、最大高さ 10 μm 程度の微細凹凸 (テクスチャ) を受光面及び裏面の両面に形成する。続いて、種々の方法により基板に PSG 層を形成して、ドーパントを熱拡散させて n 型拡散層 2 を形成する。さらに受光面には TiO₂ 又は SiN を、例えば 70 nm 程度の膜厚で堆積させて、反射防止膜 3 を形成する。次に、アルミニウムを主成分とする裏面電極用ペーストを、裏面外周部を除く裏面全面にわたり印刷し、焼成することにより裏面電極 4 を形成すると同時に、p⁺ 高濃度層である Back Surface Field (BSF) 層 5 を形成し、銀ペーストにより電極 6 を形成する。一方、受光面電極 7 は、銀を主成分とする受光面電極用ペーストを、

例えば幅100～200 μ m程度の楕形状に印刷、焼成することにより形成する。

【0004】

このような手法は、デバイスを構成する上で必要最小限の工程数となっているにもかかわらず、エネルギー変換効率等の太陽電池の特性を高める様々な効果が付随している点で優れた手法である。例えば、基板に拡散層を形成する際のドーパントの熱処理工程では、その後の低温熱処理におけるゲッタリング作用により、少数キャリアのバルクライフタイムを改善する働きがある。また、裏面電極を形成する際、裏面に印刷したアルミニウムの焼成は、電極を形成すると同時に裏面に電界層(BSF)効果のあるp⁺高濃度層を形成することができる。さらに、反射防止膜は、光学的效果(反射率低減)とともに、シリコン表面近傍で発生する少数キャリアの再結合速度を低減する働きがある。

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このような必要最小限の工程数とこれによって得られるいくつかの有用な効果により、民生用太陽電池は以前より高効率化及び低コスト化が図られている。

【0005】

少数キャリアのバルクライフタイムを改善する熱処理方法については、特開2005-116906号公報や、特開2005-129714号公報(特許文献1, 2)に提案されている。特許文献1には、p型シリコン基板の裏面にボロンを熱拡散させた後、表面にリンを熱拡散させ、次いでアニール処理する方法が提案されており、特許文献2には、シリコン基板表面にリンを熱拡散させてPSG層及びリン拡散層を形成した後、酸処理してPSG層を除去し、熱処理する方法が提案されている。しかしながら、これらの熱処理方法は、金属不純物を効果的にゲッタリングするには十分ではない。

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【0006】

さらに、特許文献2では、リンの熱拡散とその後の熱処理の2つの熱処理の間に酸処理によるPSG層除去工程が含まれており、それに伴う基板の移載作業が煩雑である。また、一般的には、pn接合形成及びゲッタリング処理を行う二段階の熱処理工程は、同一炉内で連続して行うものであるが、石英管及びヒータへの負担低減の観点から熱処理炉の降温レートに限界があり、熱処理にかかる時間が長くなってしまいう問題があった。そのため、基板1枚当たりに要する処理時間が長くなり、装置数増大によるコスト増に繋がっていた。

【先行技術文献】

【特許文献】

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【0007】

【特許文献1】特開2005-116906号公報

【特許文献2】特開2005-129714号公報

【発明の概要】

【発明が解決しようとする課題】

【0008】

本発明は、上記事情に鑑みなされたものであって、少数キャリアバルクライフタイムの高い、高効率な太陽電池を安価に製造できる太陽電池の製造方法及びこの製造方法によって得られる太陽電池を提供することを目的とする。

【課題を解決するための手段】

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【0009】

本発明者らは、上記目的を達成するため鋭意検討した結果、シリコン基板を、この基板とは異なる導電型の不純物存在下で高温熱処理して不純物拡散層を形成した後、この不純物拡散層に電気的に接続する電極を形成して太陽電池を製造するに際し、上記高温熱処理して不純物拡散層を形成した後、この高温熱処理温度よりも低い温度で、好ましくは高温熱処理炉とは異なる熱処理炉を用いて低温熱処理を行うことで、基板中に存在する鉄や亜鉛等の金属不純物をn型拡散層、PSG(リン珪酸塩)層等のデバイス不活性な領域内にゲッタリング(捕獲)して、少数キャリアバルクライフタイムの高い基板を作製することができ、高効率な太陽電池を安価に製造できることを見出し、本発明をなすに至った。

【0010】

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従って、本発明は、下記の太陽電池の製造方法及び太陽電池を提供する。

請求項 1：

シリコン基板を、これとは異なる導電型の不純物存在下で高温熱処理して該基板表面上記不純物を拡散した不純物拡散層を形成した後、この不純物拡散層に電氣的に接続する電極を形成する工程を含む太陽電池の製造方法であって、上記高温熱処理後、上記高温熱処理温度より低い温度で上記基板を低温熱処理することを特徴とする太陽電池の製造方法。

請求項 2：

高温熱処理及び低温熱処理を別々の熱処理炉で行う請求項 1 記載の太陽電池の製造方法。

請求項 3：

低温熱処理温度が、600～800℃である請求項 1 又は 2 記載の太陽電池の製造方法。

請求項 4：

低温熱処理時間が、15～75 分間である請求項 1 乃至 3 のいずれか 1 項記載の太陽電池の製造方法。

請求項 5：

高温熱処理及び低温熱処理において、それぞれの処理温度の±50℃以内の温度に保持した熱処理炉内に基板を直接入れて熱処理した後、該基板を上記炉内から直接取り出す請求項 1 乃至 4 のいずれか 1 項記載の太陽電池の製造方法。

請求項 6：

請求項 1 乃至 5 のいずれか 1 項記載の太陽電池の製造方法により製造されたことを特徴とする太陽電池。

【発明の効果】

【0011】

本発明によれば、基板の少数キャリアバルクライフタイムを向上させることができ、変換効率の高い太陽電池を作製することができる。また、温度の異なる二段階の高温及び低温熱処理を別々の熱処理炉で連続して行うことで、長大な炉内降温時間を省略することができるため、熱処理工程全体の処理時間が短縮でき、大幅なコスト削減に繋がる。

【図面の簡単な説明】

【0012】

【図 1】一般的な太陽電池の構造の一例を示す概略断面図である。

【図 2】本発明に係る太陽電池の製造方法の一例を示す説明図である。

【図 3】本発明に係る太陽電池の製造工程の一例を示す概略断面図である。(a)は基板、(b)は不純物拡散層を形成した状態、(c)は接合分離した状態、(d)は表面保護膜(反射防止膜)を形成した状態、(e)は表面及び裏面電極を形成した状態、(f)はBSF層を形成した状態をそれぞれ示す。

【図 4】ゲッターリング効果の温度依存性を表すグラフである。

【図 5】ゲッターリング効果の時間依存性を表すグラフである。

【発明を実施するための形態】

【0013】

以下、本発明に係る太陽電池の製造方法の一実施形態について図面を参照しながら説明するが、本発明は下記の実施形態に限定されるものではない。下記実施形態は例示であり、本発明の技術的思想と実質的に同一な構成を有し、同様な作用効果を奏するものは、如何なるものであっても本発明の技術的範囲に包含される。

【0014】

本発明の太陽電池の製造方法は、シリコン基板を、これとは異なる導電型の不純物存在下で高温熱処理して該基板表面(受光面)に上記不純物を拡散した不純物拡散層を形成した後、この不純物拡散層に電氣的に接続する電極を形成する工程を含む太陽電池の製造方法であって、上記高温熱処理後、上記高温熱処理温度より低い温度で上記基板を低温熱処

理することを特徴とする。

【0015】

本発明の太陽電池は、例えば図2に示す工程に従って製造することができる。また、図3には、図2の工程によって製造される太陽電池の各工程における断面の構造を示す。まず、図3(a)に示すように、ボロン(B)、ガリウム(Ga)等のIII族元素をドーピングしたp型単結晶シリコン基板1を用意する(図3(a))。このシリコン単結晶基板は、チョクラスキー(CZ)法及びフロートゾーン(FZ)法のいずれの方法によって作製されていても構わない。基板の比抵抗は、例えば $0.1 \sim 20 \Omega \cdot \text{cm}$ が好ましく、特に $0.5 \sim 2.0 \Omega \cdot \text{cm}$ であることが高い性能の太陽電池を製造する上で好適である。なお、シリコン基板としては、リン(P)、ヒ素(As)等のV族元素をドーピングしたn型単結晶シリコン基板を用いてもよく、p型又はn型多結晶シリコン基板でもよい。

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【0016】

次に、基板1を水酸化ナトリウム水溶液に浸し、ダメージ層をエッチングで取り除く。この基板のダメージ除去は、水酸化カリウム等強アルカリ水溶液を用いても構わない。また、フッ酸と硝酸の混酸であるフッ硝酸等の水溶液でも同様の目的を達成することが可能である。

【0017】

ダメージエッチングを行った基板1にランダムテクスチャを形成する。太陽電池は、通常、表面に凹凸形状を形成するのが好ましい。その理由は、可視光域の反射率を低減させるために、できる限り2回以上の反射を受光面で行わせる必要があるためである。これらランダムテクスチャの一つ一つの山のサイズは $1 \sim 20 \mu\text{m}$ 程度でよい。代表的な表面凹凸構造としてはV溝、U溝が挙げられる。これらは研削機を利用して形成可能である。また、ランダムな凹凸構造を作るには、水酸化ナトリウムにイソプロピルアルコールを加えた水溶液に浸したウェットエッチングを用いる方法や、他には、酸エッチングや、リアクティブ・イオン・エッチング等を用いることができる。なお、図1及び図3では両面に形成したテクスチャ構造は微細なため省略している。

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【0018】

次に、基板と異なる導電型の不純物を用いて基板表面に不純物拡散層を形成する。例えば、p型シリコン基板を用いる場合、不純物としてリン等を用い、不純物拡散層としてリン拡散層(n型拡散層)2を高温熱処理により形成する(図3(b))。このリン拡散層を形成するためのリンドーパントの供給源となるPSG層の形成には、熱処理炉内において POCl_3 等のガスを使用する気相拡散法や、熱処理前に基板表面にリン酸等を含む塗布剤を予め塗布してから熱処理を行う塗布拡散法などを使用することができる。

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【0019】

高温熱処理は、 $800 \sim 1050^\circ\text{C}$ 、特に 800°C 超 1050°C 以下で $10 \sim 60$ 分間行うことが好ましいが、より好ましくは $850 \sim 1000^\circ\text{C}$ の温度で $20 \sim 50$ 分である。これにより、PSG層を形成することができ、リンドーパントが拡散して基板表面に適度な濃度のリン拡散層を形成することが可能となる。

【0020】

この高温熱処理の後に低温熱処理を行う。低温熱処理は $600 \sim 800^\circ\text{C}$ で行うことが好ましい。この温度範囲から外れると、ゲッタリング効果が大幅に低下する場合がある。より好ましくは 600°C 超 800°C 未満であり、さらに好ましくは $650 \sim 750^\circ\text{C}$ の温度である。低温熱処理することで、拡散現象により基板内の鉄や亜鉛等の金属不純物がn型拡散層、PSG層等にゲッタリングにより捕獲され、少数キャリアのバルクライフタイムを向上させることができる。上記の低温熱処理におけるリン拡散層の熱処理温度に依存したゲッタリング現象は、低温熱処理温度が低すぎると金属不純物の拡散が進行しないため、ゲッタリング効果が小さい場合があり、高すぎると拡散に必要な熱量が必要以上に与えられるため、一度ゲッタリングした金属不純物が再拡散してバルクライフタイムを低下させる場合がある。

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【0021】

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また、低温熱処理は15～75分間、特に20～75分間行うことが好ましく、より好ましくは30～60分間である。バルクライフタイムを低下させる金属不純物が効果的にゲッタリングされれば、短時間の処理で十分となり、逆に上述したゲッタリング効果の高い温度から外れれば、バルクライフタイムを向上させるのに時間がかかる。

【0022】

本発明における高温と低温の二段階の熱処理におけるプロセスガスは特に限定はされないが、一般的には窒素やアルゴンなどの不活性ガスや、酸素などの酸化性ガスが用いられる。ただし、高温熱処理時に酸素ガス雰囲気が強くなると、シリコンと反応して熱酸化膜が成長するため拡散濃度が変化するおそれがある。高温熱処理における窒素ガス供給量は20～60slm程度が好ましく、窒素以外にアルゴン等のガスを用いた雰囲気にしてもよい。また、低温熱処理における酸素ガス供給量は3～10slm程度が好ましい。

【0023】

また、リン等の不純物拡散層を形成する高温熱処理と、その後の低温熱処理の二段階の熱処理を異なる炉で行い、それぞれ温度一定の条件で基板を直接入れて取り出しを行うことで、通常は同一炉内処理で必要となる長大な降温時間を省略することが可能となり、熱処理工程の大幅な時間短縮が可能となり、基板の搬送時間及び熱処理時間を合わせて65分以上、特に90～135分間の処理時間とすることができる。特に、基板を炉に出し入れする際、高温熱処理と低温熱処理で、熱処理炉内の温度をそれぞれの処理温度の±50℃以内、好ましくは±30℃以内の温度に保持した状態で、炉内に基板を直接入れて熱処理し、処理後基板を直接取り出すことが好ましい。所定温度で基板を炉内に直接入れて直接取り出すことで、長大な炉内降温時間を省略することが可能となる。基板を炉内に入れる際及び取り出す際の温度が上記範囲を外れると目標とする拡散濃度やバルクライフタイムが得られなくなる場合がある。

【0024】

ここで、リン等の不純物拡散層を形成する高温熱処理と低温熱処理は処理温度が異なるため、不純物拡散層の濃度と深さで決定されるシート抵抗は高温熱処理条件に依存する。この不純物拡散層のシート抵抗は、電極とのオーミックコンタクトを得る目的で、面内均一な拡散層であるシングルエミッタ構造では、 $40 \sim 50 \Omega/\square$ とすることが好ましい。また、リンドーパントの表面濃度は、一般的にSIMS（二次イオン質量分析法）で測定することが可能であり、電極とのオーミックコンタクトを得るために、表面リンドーパント濃度が $1.0 \times 10^{19} \text{ cm}^{-3}$ 以上、特に $1.0 \times 10^{19} \sim 1.0 \times 10^{20} \text{ cm}^{-3}$ であることが好ましい。

【0025】

上記のように、基板表面全体に一定濃度のリン等の不純物拡散層を形成したシングルエミッタ構造とは異なる不純物拡散層の形成手法として、受光面電極直下のみを高濃度拡散層にして、それ以外の受光面領域はこれより不純物濃度の低い低濃度拡散層とするセレクトティブエミッタ構造とすることも可能である。このようなセレクトティブエミッタ構造により、オーミックコンタクトを得ながら、電極以外の受光面の表面再結合及びエミッタ内の再結合を抑制することにより、光電変換効率を向上させることができる。

【0026】

熱処理後、プラズマエッチング装置を用い、接合分離を行う（図3（c））。このプロセスでは、プラズマやラジカルが受光面や裏面に侵入しないよう、サンプルをスタックし、その状態で端面（側面）を数 μm 削る。これにより、太陽電池にした場合の漏れ電流を防ぐことができる。

【0027】

引き続き、表面に形成されたPSG層を5～25質量%のフッ酸でエッチングした後、ダイレクトプラズマCVD装置等を用い、エミッタ層上に表面保護膜である窒化珪素膜3を堆積する（図3（d））。この膜厚は、反射防止膜も兼ねさせるため70～100nmが適している。他の反射防止膜として酸化珪素膜、二酸化チタン膜、酸化亜鉛膜、酸化スズ膜等があり、代替が可能である。また、形成法も上記以外にリモートプラズマCVD法

、コーティング法、真空蒸着法等があるが、経済的な観点から、窒化珪素膜をダイレクトプラズマCVD法によって形成するのが好ましい。

さらに、上記反射防止膜上にトータルの反射率が最も小さくなるような条件、例えば二フッ化マグネシウム膜といった屈折率が1～2の間の膜を形成すれば、反射率がさらに低減し、生成電流密度は高くなる。

【0028】

次に、スクリーン印刷装置等を用い、裏面に、例えば銀ペースト6やアルミニウムペースト4を塗布し、乾燥させる（図3（e））。さらに表面側もスクリーン印刷装置等を用い、楕形電極パターン印刷版等を用いて銀電極7を印刷し、乾燥させる。

【0029】

その後、最高温度700～800℃で1分間以下の焼成を行うRapid Thermal Processing（RTP；高速熱処理）焼成を行い、裏面電極及び表面楕形電極を形成する。この焼成工程により、電極ペースト中のガラスフリットがシリコンの自然酸化膜及びシリコン窒化膜をファイアスルーして、電極と拡散層との電気的な導通が達成される。また、裏面にアルミニウム電極を形成すると同時に、 p^+ 高濃度層であるBSF層5が形成され、電界効果によって裏面アルミニウム電極近傍のシリコン表面において少数キャリアの追い返しが起こり、その結果、基板の少数キャリアバルクライフタイムが向上する（図3（f））。なお、これら電極形成は、真空蒸着法、スパッタリング法等、上記印刷法だけによらずとも可能である。

以上の工程により、図1に示すような太陽電池を簡単な手法で製造することができる。

【0030】

なお、本発明の太陽電池の製造方法の一実施形態としてp型ボロンドープ基板を用いて説明したが、本発明はこれに限定されるものではなく、例えばp型ガリウムドープ基板やn型リンドープシリコン基板を使用してもよく、さらにリン拡散層に加えてリン拡散層を形成した領域とは異なる領域にボロン拡散層を形成したようなシリコン基板を使用してもよい。

【実施例】

【0031】

以下、実施例及び比較例を示し、本発明をより具体的に説明するが、本発明は下記の実施例に制限されるものではない。

【0032】

〔実施例1〕

結晶面方位（100）、15.65cm角200 μ m厚、アズスライス比抵抗2 $\Omega \cdot \text{cm}$ （ドーパント濃度 $7.2 \times 10^{15} \text{cm}^{-3}$ ）ボロンドープp型単結晶シリコン基板を用意した。

続いて、n型拡散層を形成するためにリンドーパント源となるリン酸を含むリン塗布液（濃度2質量%）を受光面側にスピン塗布して200℃で10分間乾燥させた。

次に、リン拡散層を形成する高温熱処理工程と、その後の低温熱処理工程の二段階の熱処理工程を異なる熱処理炉で行った。まず、高温熱処理炉において、920℃に保持した炉にリンを塗布した基板を投入して、30分の熱処理を行った後、基板を取り出した。基板の投入時及び取り出し時の炉内温度は920℃であった。この高温熱処理における条件は、流量が20slmの窒素雰囲気下で、表面シート抵抗が約45 $\Omega/\square$ になるように熱処理温度、熱処理時間及びリン塗布液の濃度を調整した。

【0033】

次に、高温熱処理した基板を、異なる熱処理炉を用いて低温熱処理を行った。その低温熱処理温度は450、500、550、600、650、700、750、800及び850℃でそれぞれ30分間熱処理を行った。また、プロセスガスは酸素ガスを使用し、その流量は5slmであった。基板の投入時及び取り出し時の炉内温度はそれぞれ上記熱処理温度と同じ温度であった。

なお、1つの熱処理において、基板の搬送時間は、炉に入れる時間と出す時間を合計し

て15分かかるため、本実施例の異なる熱処理炉で二段階の熱処理を行うと合計30分の搬送時間を要する。

【0034】

次いで、一般的な CF_4 ガス及び酸素ガスを用いたプラズマエッチング装置を用いて端面のリン拡散層をエッチングし、受光面と裏面側とのpn接合分離を行った。

その後、基板表面のPSG層を25質量%のフッ酸水溶液で除去し、洗浄を行った。

続いて、ダイレクトプラズマCVD装置を用いてモノシラン(SiH_4)とアンモニア(NH_3)の混合ガスにより、シリコン窒化膜を受光面全体に膜厚80nm形成し、反射防止膜とした。

最後に、受光面側に銀ペースト、裏面側にアルミニウムペーストと銀ペーストを電極印刷し、200℃で10分乾燥後、最高温度が750℃で1分以下のRTP焼成を行い、受光面電極及び裏面電極を形成し、太陽電池を作製した。

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【0035】

[比較例1]

920℃で30分間高温熱処理した基板を低温熱処理しない以外は実施例1と同様に処理して太陽電池を作製した。

【0036】

[実施例2]

920℃で30分間高温熱処理した基板に、550℃で15、45、60及び75分間の低温熱処理をそれぞれ施した以外は実施例1と同様に処理して太陽電池を作製した。

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【0037】

[実施例3]

低温熱処理温度700℃で処理した以外は実施例2と同様に処理して太陽電池を作製した。

【0038】

[実施例4]

低温熱処理温度850℃で処理した以外は実施例2と同様に処理して太陽電池を作製した。

【0039】

[参考例1]

同一の熱処理炉を用いて降温工程を含む二段階の熱処理を行った以外は実施例1と同様に処理して太陽電池を作製した。熱処理は、具体的には920℃に保持した炉にリン塗布剤を塗布した基板を投入し、流量20slmの窒素雰囲気下、920℃で30分間保持し、その後、流量5slmの酸素ガス雰囲気に切り替え、降温レート3℃/分で700℃まで降温し、最後に700℃で30分保持して、炉から基板を取り出した。

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【0040】

特性評価

実施例1～4、比較例1及び参考例1における熱処理条件と、基板の少数キャリアバルクライフタイムの結果を表1に示す。なお、基板の少数キャリアバルクライフタイムの測定方法は、一般的なcp法を利用した。具体的には、熱処理工程後の基板を25質量%HF水溶液に浸して表面のPSG層を除去し、さらにKOH溶液などのアルカリエッチング溶液に浸して表面拡散層除去後、ヨウ素-メタノール溶液による表面ケミカルパッシベーション処理により、基板の少数キャリアのバルクライフタイムをSemilab社製WT-2000装置により測定した。

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【0041】

実施例1～4、比較例1及び参考例1で得られた太陽電池を、25℃の雰囲気の中、ソーラーシミュレータ(光強度:1kW/m², スペクトル:AM1.5グローバル)の下で電流電圧特性を測定した。結果を表2に示す。また、バルクライフタイムとの相関を見るために各条件のバルクライフタイムデータも併せて示した。なお、表中の太陽電池特性の数値は、それぞれ上記実施例、比較例及び参考例で作製したセル10枚の平均値である

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【 0 0 4 2 】

【表 1】

		高温 熱処理 温度 (℃)	高温 熱処理 時間 (分)	低温 熱処理 温度 (℃)	低温 熱処理 時間 (分)	合計 搬送 時間 (分)	総処理時間 (熱処理+搬送) (分)	パルク ライフ タイム (μ s)
実施例1	a	920	30	450	30	30	90	77
	b	920	30	500	30	30	90	97
	c	920	30	550	30	30	90	124
	d	920	30	600	30	30	90	189
	e	920	30	650	30	30	90	305
	f	920	30	700	30	30	90	375
	g	920	30	750	30	30	90	301
	h	920	30	800	30	30	90	218
	i	920	30	850	30	30	90	132
実施例2	j	920	30	550	15	30	75	89
	k	920	30	550	45	30	105	159
	l	920	30	550	60	30	120	223
	m	920	30	550	75	30	135	278
実施例3	n	920	30	700	15	30	75	225
	o	920	30	700	45	30	105	379
	p	920	30	700	60	30	120	372
	q	920	30	700	75	30	135	380
実施例4	r	920	30	850	15	30	75	116
	s	920	30	850	45	30	105	198
	t	920	30	850	60	30	120	242
	u	920	30	850	75	30	135	267
比較例1		920	30	—	—	15	45	68
参考例1		920	30	700	30	15	148 (降温時間73分 含む)	325

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【 0 0 4 3 】

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【表 2】

		高温 熱処理 温度 (℃)	高温 熱処理 時間 (分)	低温 熱処理 温度 (℃)	低温 熱処理 時間 (分)	バルク ライフ タイム (μ s)	開放 電圧 (mV)	短絡 電流 (mA/cm ²)	フィル ファクタ (%)	変換 効率 (%)
実施例1	a	920	30	450	30	77	618	34.2	79.0	16.7
	b	920	30	500	30	97	619	34.3	79.2	16.8
	c	920	30	550	30	124	620	34.5	78.9	16.9
	d	920	30	600	30	189	623	34.8	78.8	17.1
	e	920	30	650	30	305	627	34.7	79.0	17.2
	f	920	30	700	30	375	629	34.8	79.1	17.3
	g	920	30	750	30	301	628	34.6	79.1	17.2
	h	920	30	800	30	218	625	34.5	79.2	17.1
	i	920	30	850	30	132	621	34.7	78.8	17.0
実施例2	j	920	30	550	15	89	619	34.3	79.1	16.8
	k	920	30	550	45	159	622	34.6	78.9	17.0
	l	920	30	550	60	223	623	34.8	78.8	17.1
	m	920	30	550	75	278	625	34.5	79.3	17.1
実施例3	n	920	30	700	15	225	623	34.7	79.0	17.1
	o	920	30	700	45	379	630	34.8	78.9	17.3
	p	920	30	700	60	372	629	34.7	79.2	17.3
	q	920	30	700	75	380	630	34.7	79.1	17.3
実施例4	r	920	30	850	15	116	620	34.6	78.8	16.9
	s	920	30	850	45	198	623	34.5	79.0	17.0
	t	920	30	850	60	242	624	34.6	79.2	17.1
	u	920	30	850	75	267	625	34.8	78.8	17.1
比較例1		920	30	—	—	68	616	34.0	79.2	16.6
参考例1		920	30	700	30	325	628	34.7	78.9	17.2

【0044】

表1及び表2の結果より、熱処理工程後に測定したバルクライフタイムの値とその条件の太陽電池は変換効率において正の相関があることが分かる。

図4に低温熱処理温度とバルクライフタイムの関係を、図5に低温熱処理時間とバルクライフタイムの関係を示した。それぞれの図には、比較例1及び参考例1のバルクライフタイム値を参考として入れた（比較例1の低温熱処理条件は0℃、0分とした。）。

【0045】

図4において、ゲッターリング効果の高い熱処理温度が650～750℃であることが分かる。また図5において、低温熱処理温度が低い場合（<600℃）、あるいは高い場合（800℃<）でもバルクライフタイムが飽和するのに時間がかかり、中間の700℃条件では、30分でバルクライフタイム及びセル特性が飽和しており、参考例1と比べても同等以上のバルクライフタイム値が得られている。

【0046】

この熱処理温度に依存したゲッターリング現象は、600℃より低いと金属不純物の基板中の拡散が進行しないため、ゲッターリング効果が小さく、800℃より高いと拡散に必要

な熱量が十分に与えられるため、一度ゲッタリングした金属不純物が再度デバイス活性領域に拡散してバルクライフタイムを低下させているためである。

【0047】

本発明により、高効率な太陽電池を作製するために必要な高いバルクライフタイムを有する基板を短時間の熱処理工程で作製することが可能となった。

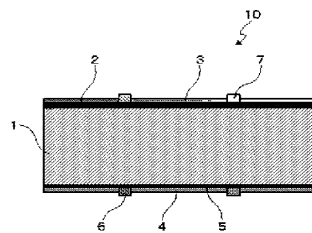
【符号の説明】

【0048】

- 1 (p型) シリコン基板
- 2 n型拡散層
- 3 表面保護膜 (反射防止膜)
- 4 裏面電極
- 5 B S F 層
- 6 裏面電極
- 7 表面電極
- 10 太陽電池

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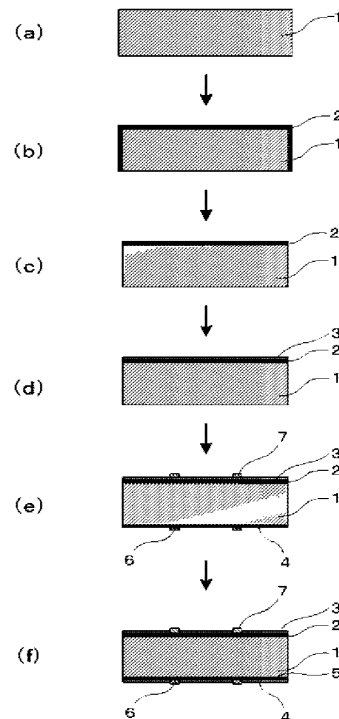
【図1】



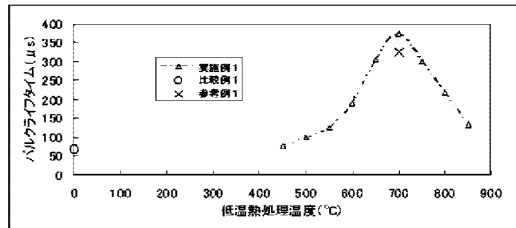
【図2】

ダメージニッチング/テクスチャ形成
洗浄
リン拡散剤塗布/ペーカ
高温熱処理 (pn接合形成)
低温熱処理 (ゲッタリング)
接合分離
ガラスエッチング/洗浄
CVD (反射防止膜形成)
裏面電極印刷/乾燥
表面電極印刷/乾燥
焼成

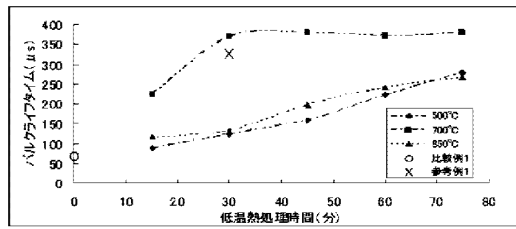
【図3】



【図 4】



【図 5】



フロントページの続き

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CB27 CB28 CB29 CB30 GA20

5F151 AA02 AA03 CB12 CB13 CB14 CB15 CB20 CB21 CB22 CB24

CB27 CB28 CB29 CB30 GA20



Espacenet

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Preparation method of CIGS (copper indium gallium diselenide) thin-film solar cell

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Abstract of CN102694077 (A)

The invention relates to a preparation method of a CIGS (copper indium gallium diselenide) thin-film solar cell. The preparation method comprises the steps of: a) preparing a molybdenum back electrode on a substrate; b) preparing a CIGS absorbing layer on the molybdenum back electrode; c) conducting annealing treatment; d) preparing an In₂Se₃ or ZnS buffer layer on the CIGS absorbing layer; e) preparing an intrinsic zinc oxide high-impedance layer on the In₂Se₃ or ZnS buffer layer; f) preparing an indium tin oxide thin-film low-impedance layer on the intrinsic zinc oxide high-impedance layer; and g) preparing an aluminum electrode on the indium tin oxide thin-film low-impedance layer.



Patent Translate

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DESCRIPTION CN102694077

The invention relates to a method for preparing a copper indium gallium selenide thin film solar cell, comprising: a) preparing a molybdenum back electrode on a substrate; b) preparing a copper indium gallium selenide absorption layer on the molybdenum back electrode; c) performing annealing Processing; d) preparing an InSe or ZnS buffer layer on the copper indium gallium selenide absorber layer; e) preparing an intrinsic zinc oxide high resistance layer on the InSe or ZnS buffer layer; f) in the intrinsic zinc oxide high impedance A low-impedance layer of indium tin oxide film is prepared on the layer; g) an aluminum electrode is prepared on the low-impedance layer of the indium tin oxide film.

Method for preparing copper indium gallium selenide thin film solar cell

Technical field:

The present invention relates to the field of solar cells, and more particularly to a method for preparing a copper indium gallium selenide thin film solar cell absorber layer.

Background technique:

As is well known, the copper indium gallium selenide compound has a chalcopyrite structure and can be prepared as a material for solar power generation on a soft or rigid substrate, and the copper indium gallium selenide thin film solar cell thus produced has the advantages of high stability and low cost. . At present, the energy available on the earth is becoming shorter and shorter, and it is an indisputable fact that petrochemical energy will emit carbon and sulfur oxides during use, causing air pollution and aggravating the global warming

effect of the earth. . Therefore, the development of pollution-free renewable energy is one of the top research projects in the world. Solar energy is a pollution-free energy source and one of the best choices for renewable energy. The development of solar energy is primarily the development of materials that produce high efficiency conversion of solar energy into electrical energy.

The copper indium gallium selenide compound material is a compound semiconductor material having a chalcopyrite structure, which is a direct band gap material, can absorb sunlight having a large wavelength range, and has self-modulating self-composition to form a pn junction, and is recognized. One of the best materials for the absorption layer of solar cells, such as copper indium gallium diselenide (Cu(InGa)Se_2), referred to as CIGS, is the semiconductor material with the highest light absorption capability. Due to the high light absorption rate advantage of CIGS, the thickness of the CIGS absorber layer can be 1~2 μm . Generally, the cost of CIGS material is only 0.03 US dollars/watt in mass production manufacturing, so it is highly competitive and promising. Solar power generation can be the same or even lower than traditional fossil fuel power generation. Therefore, how to prepare a low-cost, high-efficiency copper indium gallium selenide solar thin film battery is one of the most worthy research topics.

CIGS thin-film solar cells have two advantages: 1 is that the photoelectric conversion layer can be very thin, a few microns; second, its band gap (forbidden band width) can be controlled by the ratio of Ga (gallium) in the proportion of copper indium gallium selenide compound. According to the prior art, the ratio of Ga and In has the following relationship with the band gap (E_g), $E_g(\text{eV}) = 1.02 + 0.67y + 0.11y(y-1)$, wherein the atomic content of $y = \text{In}/(\text{Ga} + \text{In})$ proportion. The theory shows that a single bandgap solar cell can not make the maximum use of solar energy, that is, the photon energy is too small to generate electron-hole pairs, and the photon with too much energy can only excite an electron-hole pair, excess energy. It can only be converted into heat that is not conducive to the efficiency of solar cells. Therefore, from the perspective of improving the efficiency of solar cells, it is hoped that solar cells have a lot of band gaps to absorb as much solar energy as possible, and the tunable characteristics of the band gap of CIGS compounds can precisely realize such an idea. The content ratio of Ga can be adjusted in the preparation of the CIGS film. Increasing the ratio of Ga increases the band gap of the CIGS compound.

The methods for preparing CIGS films have been described in the prior art as: (1) selenization, (2) lamination, (3) multi-source (two or three source) evaporation, (4) sputtering, (5) deposition method, (6) spray method, (7) spin coating method, (8) vacuum heating synthesis method, and the like. And (1) selenization method, (2) lamination method, (3) multi-source (two or three source) evaporation method, (4) sputtering method requires vulcanization of CIGS film in a certain process flow or Selenization treatment, by Sulphurization or selenization treatment, S and Se atoms can be reacted with Cu-In-Ga by diffusion to form CuInGaSe compound, which is called vulcanization or selenization.

There are some disadvantages in the method of selenization to prepare a thin film solar cell having a chalcopyrite structure, such as a long production cycle, a large energy consumption, consumption of Se, a high toxicity of Se, a poor distribution of Se, a gradient of Se, and the like.

In addition, for the gradient distribution process of regulating Ga, the above various processes are relatively difficult to implement in one step. For example, the three-stage co-evaporation method developed by the NREL laboratory in the United States realizes that the above-mentioned band gap gradient A or V-shaped band gap gradient is involved in the evaporation reaction in three different elements, and the process is very complicated and requires precise control in real time. Can be achieved. Although this method can prepare a solar thin film battery with high conversion efficiency, it is disadvantageous for low-cost, large-area, large-scale production.

Summary of the invention

The invention provides a preparation method of a copper indium gallium selenide thin film solar cell, which comprises:

a) preparing a molybdenum back electrode on the substrate;

b) preparing a copper indium gallium selenide absorber layer on the molybdenum back electrode: using a vacuum magnetron sputtering method, using a $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ alloy target for sputtering, and setting a CuGaSe_2 alloy target with $x=0$ as the target 1, setting $x=0.8$ The $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ alloy target of 0.6 is the target 2, and the target 1 is first sputtered for 2 to 4 minutes at any high power density between high power density $4\text{W}/\text{cm}^2$ to $8\text{W}/\text{cm}^2$, and then The target 1 and the target 2 are co-sputtered, and the initial power density for sputtering the target 2 at this time is any low power density between $0.3\text{ W}/\text{cm}^2$ and $1\text{ W}/\text{cm}^2$, and the target 1 is The high power density for sputtering is set to continuously decrease in operation, and in the state where the target 1 and the target 2 are co-sputtered, when the power density of the sputtering of the target 1 is continuously decreased, the target 2 is simultaneously The power density at which sputtering is performed is continuously increasing, and finally, until the power density for sputtering of the target 1 is decreased to any low power density between $0.3\text{ W}/\text{cm}^2$ and $1\text{ W}/\text{cm}^2$, the target 2 is subjected to The power density of sputtering is increased to any high power density between $4\text{ W}/\text{cm}^2$ and $8\text{ W}/\text{cm}^2$, and the time for performing co-sputtering is 30-60 minutes, so that Ga in the copper indium gallium selenide absorption layer concentrated Gradient is formed, in which the concentration of the side absorbent layer in contact with the highest Mo back electrode, the lowest concentration at the opposite other side of the absorbent layer;

c) annealing treatment: annealing the copper indium gallium selenide absorber layer in a vacuum chamber in a

rapid heating manner, the temperature is 400°C to 600°C , and the annealing time is 55 to 90 seconds;

d) preparing a buffer layer of In_2Se_3 or ZnS on the copper indium gallium selenide absorber layer, the thickness of which is 80 to 120 nm;

e) preparing an intrinsic zinc oxide high-resistance layer on the In_2Se_3 or ZnS buffer layer, having a thickness of 0.1 to $0.5\ \mu\text{m}$;

f) preparing a low-impedance layer of indium tin oxide film on the intrinsic zinc oxide high-resistance layer, having a thickness of 0.3 to $0.8\ \mu\text{m}$;

g) preparing an aluminum electrode on a low-impedance layer of an indium tin oxide film.

Wherein: the thickness of the copper indium gallium selenide absorber layer is from 1.5 micrometers to 2 micrometers.

Wherein: in performing step b), the working pressure in the sputtering chamber is 1×10^{-4} Torr, and the temperature of the substrate is maintained at any temperature between 350°C . and 450°C .

Wherein: in the performing step d), using the vacuum magnetron sputtering method, using the In_2Se_3 or ZnS alloy target, the working pressure of the vacuum magnetron sputtering is $1-5 \times 10^{-3}$ Torr and the Ar gas is introduced, and the lining is performed. The temperature of the bottom is kept at room temperature.

Wherein: in the performing step e), using the RF vacuum magnetron sputtering method, the target is intrinsic zinc oxide, and the working pressure of the RF vacuum magnetron sputtering is $1-5 \times 10^{-3}$ Torr, and the operating frequency is 400K~2MHz, and Ar gas is introduced, and the temperature of the substrate is kept at room temperature.

Among them: vacuum DC magnetron sputtering method, the target is indium tin oxide In_2O_3 : SnO_2 , In_2O_3 : SnO_2 mass ratio is 9:1, vacuum DC magnetron sputtering working pressure is $1-5 \times 10^{-3}$ Torr, and Ar gas doped with 2% to 5% O_2 was introduced, and the temperature of the substrate was kept at room temperature.

According to the method of the present invention, the selenization-free process flow and the cadmium-free In_2Se_3 or ZnS buffer layer can not only avoid the toxic gases of H_2Se and H_2S , but also use cadmium-free compounds, which is environmentally friendly and can reduce costs, and enables the production process. The equipment has the advantages of simple energy consumption and short production cycle.

Compared with the prior art, the present invention has the following advantages: all the processes of the present invention are dry process processes, and the process does not use chemical solvents and solutions. The absorption layer of the solar cell can be obtained in one step to obtain a stable crystalline absorption layer, eliminating the need for an industrial process for selenization or vulcanization of the absorption layer, which greatly shortens the production cycle, reduces production equipment, and avoids production processes. Environmental pollution and potential dangers. The process steps of the present invention are simplified, energy consumption is small, and thus production costs are reduced.

DRAWINGS

1 is a flow chart showing a method of preparing an absorption layer of a copper indium gallium selenide thin film solar cell of the present invention;

Figure 2 is a graph of secondary ion mass spectrometry (SIMS) analysis of a solar cell absorber layer prepared in accordance with the method of the present invention.

Detailed ways

BRIEF DESCRIPTION OF THE DRAWINGS Figure 1 is a flow chart of a method for preparing an absorption layer of a copper indium gallium selenide thin film solar cell of the present invention, as shown in the figure:

The back electrode was first prepared on the substrate. The substrate may be selected from soda lime glass or stainless steel sheets, and generally 1-3 mm thick soda lime glass or 0.2 mm thick stainless steel sheets are used. A 0.8 micron thick molybdenum (Mo) metal was deposited as a back electrode by magnetron sputtering.

Then, an absorption layer is prepared on the back electrode: the invention adopts dual-target co-sputtering to prepare an absorption layer, and the target is a $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ alloy target. For convenience of explanation, a

CuGaSe₂ alloy target with x=0 may be set as the target 1, and x is set. The CuIn_xGa_{1-x}Se₂ alloy target of 0.8 to 0.6 is the target 2, for example, Cu(In_{0.7}Ga_{0.3})Se₂ alloy target 2. First, the target 1 is first sputtered for 2 to 4 minutes at any high power density between a high power density of 4 W/cm² and 8 W/cm², and then the target 1 and the target 2 are co-sputtered. The initial power density for sputtering the target 2 is any low power density between 0.3 W/cm² and 1 W/cm², and the high power density for sputtering the target 1 is set to be in operation. Continuous decrement. Since the target 1 and the target 2 are co-sputtered at this time, and in order to ensure a gradient of Ga concentration in the copper indium gallium selenide absorption layer, the power density of sputtering the target 1 and the target 2 is designed as: When the target 1 is When the power density of the sputtering is continuously decreased, the power density of sputtering on the target 2 is continuously increased, and finally the power density until sputtering of the target 1 is decreased to 0.3 W/cm² to 1 W/cm². With any low power density between cm², the power density of sputtering of target 2 is increased to any high power density between 4 W/cm² and 8 W/cm². The co-sputtering time is performed for 30 to 60 minutes so that the thickness of the copper indium gallium selenide absorber layer deposited on the molybdenum back electrode is from 1.5 micrometers to 2 micrometers. The working pressure in the sputtering chamber is 1×10^{-4} Torr, and the temperature of the substrate is maintained at any temperature between 350 °C and 450 °C. According to this process, the Ga concentration in the copper indium gallium selenide absorbing layer is gradient, the concentration of the absorbing layer on the side in contact with the Mo back electrode is the highest, and the concentration on the opposite side of the absorbing layer is the lowest.

Annealing is then carried out: the copper indium gallium selenide absorber layer is annealed in a vacuum chamber in a rapid heating manner at a temperature of 400 °C to 600 °C and an annealing time of 55 to 90 seconds. No gas is required to pass through during the annealing process. The annealed copper indium gallium selenide absorber layer has a chalcopyrite structure, and local ion diffusion is carried out by thermal energy to improve the crystallization state and improve the photovoltaic power generation efficiency of the main absorption layer of the solar cell.

Then, a buffer layer is prepared on the absorption layer: the In₂Se₃ or ZnS buffer layer is sputter deposited by using a vacuum magnetron sputtering method using an In₂Se₃ or ZnS alloy target, and the working pressure of the vacuum magnetron sputtering is $1-5 \times 10^{-3}$ Torr and Ar gas was introduced, and the temperature of the substrate was kept at room temperature. The In₂Se₃ or ZnS buffer layer is deposited to a thickness of 80 to 120 nm.

Then, an intrinsic zinc oxide high-resistance layer is prepared on the buffer layer: the target is intrinsic zinc oxide (ZnO) by RF vacuum magnetron sputtering, and the working pressure of the RF vacuum magnetron sputtering is $1-5 \times 10^{-3}$ Torr, the operating frequency is 400K~2MHz, and Ar gas is introduced, and the temperature of the substrate is kept at room temperature. The intrinsic zinc oxide high-resistance layer is deposited to a thickness of 0.1 to 0.5 μm.

Then, a low-impedance layer of indium tin oxide ($\text{In}_2\text{O}_3\text{:SnO}_2$) film is prepared on the intrinsic zinc oxide high-resistance layer: the target is indium tin oxide ($\text{In}_2\text{O}_3\text{:SnO}_2$), $\text{In}_2\text{O}_3\text{:SnO}_2$ by vacuum DC magnetron sputtering. The mass ratio was 9:1, the working pressure of vacuum DC magnetron sputtering was $1-5 \times 10^{-3}$ Torr, and Ar gas doped with 2% to 5% O_2 was introduced, and the temperature of the substrate was kept at room temperature. The low-impedance layer of the indium tin oxide film is deposited to a thickness of 0.3 to 0.8 μm .

Finally, an aluminum electrode was prepared on the low-impedance layer of indium tin oxide film: an Al electrode was prepared by a sputtering method using an Al target, and finally a copper indium gallium selenide thin film solar cell having a concentration gradient of Ga was obtained.

Figure 2 is a graph of secondary ion mass spectrometry (SIMS) analysis of a solar cell absorber layer prepared in accordance with the method of the present invention. The concentration of Ga was highest on the side of the Mo back electrode and then decreased toward the surface of the CIGS film, indicating a band gap having a gradient distribution.

Compared with the prior art, the present invention has the following advantages: all the processes of the present invention are dry process processes, and the process does not use chemical solvents and solutions. The absorption layer of the solar cell can be obtained in one step to obtain a stable crystalline absorption layer, eliminating the need for a process of selenization or vulcanization of the absorption layer, which greatly shortens the production cycle, reduces the production equipment, and avoids the production process. Environmental pollution and potential dangers. The process steps of the present invention are simplified, energy consumption is small, and thus production costs are reduced.



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CLAIMS CN102694077

1.

A method for preparing a copper indium gallium selenide thin film solar cell, comprising:

a) preparing a molybdenum back electrode on the substrate;

b) preparing a copper indium gallium selenide absorber layer on the molybdenum back electrode: using a vacuum magnetron sputtering method, using a $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ alloy target for sputtering, and setting a CuGaSe_2 alloy target with $x=0$ as the target 1, setting $x=0.8$ The $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ alloy target of 0.6 is the target 2, and the target 1 is first sputtered for 2 to 4 minutes at any high power density between high power density $4\text{W}/\text{cm}^2$ to $8\text{W}/\text{cm}^2$, and then The target 1 and the target 2 are co-sputtered, and the initial power density for sputtering the target 2 at this time is any low power density between $0.3\text{ W}/\text{cm}^2$ and $1\text{ W}/\text{cm}^2$, and the target 1 is The high power density for sputtering is set to continuously decrease in operation, and in the state where the target 1 and the target 2 are co-sputtered, when the power density of the sputtering of the target 1 is continuously decreased, the target 2 is simultaneously The power density at which sputtering is performed is continuously increasing, and finally, until the power density for sputtering of the target 1 is decreased to any low power density between $0.3\text{ W}/\text{cm}^2$ and $1\text{ W}/\text{cm}^2$, the target 2 is subjected to The power density of sputtering is increased to any high power density between $4\text{ W}/\text{cm}^2$ and $8\text{ W}/\text{cm}^2$, and the time for performing co-sputtering is 30 to 60 minutes, so that Ga in the copper indium gallium selenide absorber layer concentrated a gradient forming the highest concentration on the side of the absorption layer in contact with the Mo back electrode and the lowest concentration on the opposite side of the absorption layer;

c) annealing treatment: annealing the copper indium gallium selenide absorber layer in a vacuum chamber in a

rapid heating manner, the temperature is 400°C to 600°C , and the annealing time is 55 to 90 seconds;

d) preparing a buffer layer of In_2Se_3 or ZnS on the copper indium gallium selenide absorber layer, the thickness of which is 80 to 120 nm;

e) preparing an intrinsic zinc oxide high-resistance layer on the In_2Se_3 or ZnS buffer layer, having a thickness of 0.1 to $0.5\ \mu\text{m}$;

f) preparing a low-impedance layer of indium tin oxide film on the intrinsic zinc oxide high-resistance layer, having a thickness of 0.3 to $0.8\ \mu\text{m}$;

g) preparing an aluminum electrode on a low-impedance layer of an indium tin oxide film.

2.

The method according to claim 1, wherein the copper indium gallium selenide absorbing layer has a thickness of from $1.5\ \mu\text{m}$ to $2\ \mu\text{m}$.

3.

The preparation method according to claim 1, wherein in the performing step b), the working pressure in the sputtering chamber is 1×10^{-4} Torr, and the temperature of the substrate is maintained at 350°C to 450°C . Any temperature between 350°C and 450°C .

4.

The preparation method according to claim 1, wherein in the performing step d), the vacuum magnetron sputtering method is used, and the working pressure of the vacuum magnetron sputtering is $1-5 \times 10^{-3}$ Torr by using an In_2Se_3 or ZnS alloy target. $1-5 \times 10^{-3}$ Torr was introduced and Ar gas was introduced, and the temperature of the substrate was kept at room temperature.

5.

The preparation method according to claim 1, wherein in the performing step e), the target is intrinsic zinc oxide by radio frequency vacuum magnetron sputtering, and the working pressure of the radio frequency vacuum magnetron sputtering is $1-5 \times 10^{-3}$ Torr, operating frequency is 400K~2MHz, and Ar gas is introduced, and the temperature of the substrate is kept at room temperature.

6.

The preparation method according to claim 1, wherein the target material is indium tin oxide $\text{In}_2\text{O}_3:\text{SnO}_2$, $\text{In}_2\text{O}_3:\text{SnO}_2$ mass ratio is 9:1 by vacuum DC magnetron sputtering, vacuum DC magnetron sputtering The working pressure was $1-5 \times 10^{-5}$ Torr, and an Ar gas doped with 2% to 5% O_2 was introduced, and the temperature of the substrate was kept at room temperature.



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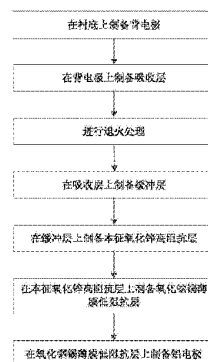
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(54) 发明名称

一种铜铟镓硒薄膜太阳能电池的制备方法

(57) 摘要

本发明涉及一种铜铟镓硒薄膜太阳能电池的制备方法,其包括:a)在衬底上制备钼背电极;b)在该钼背电极上制备铜铟镓硒吸收层;c)进行退火处理;d)在铜铟镓硒吸收层上制备 In_2Se_3 或 ZnS 缓冲层;e)在所述 In_2Se_3 或 ZnS 缓冲层上制备本征氧化锌高阻抗层;f)在所述本征氧化锌高阻抗层上制备氧化铟锡薄膜低阻抗层;g)在氧化铟锡薄膜低阻抗层上制备铝电极。



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1. 一种铜铟镓硒薄膜太阳能电池的制备方法,其包括:

a) 在衬底上制备钼背电极;

b) 在该钼背电极上制备铜铟镓硒吸收层:利用真空磁控溅射法,采用 $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ 合金靶进行溅射,设 $x=0$ 的 CuGaSe_2 合金靶为靶 1,设 $x=0.8$ 至 0.6 的 $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ 合金靶为靶 2,首先以高功率密度 $4\text{W}/\text{cm}^2$ 至 $8\text{W}/\text{cm}^2$ 之间的任意高功率密度对靶 1 先溅射 2 至 4 分钟,接着再对靶 1 和靶 2 进行共溅射,此时对靶 2 进行溅射的初始功率密度为 $0.3\text{W}/\text{cm}^2$ 至 $1\text{W}/\text{cm}^2$ 之间任意的低功率密度,而对靶 1 进行溅射的高功率密度设置成在工作中连续递减,在对靶 1 和靶 2 进行共溅射的状态下,当对靶 1 进行溅射的功率密度连续递减时,与此同时对靶 2 进行溅射的功率密度则为连续递增,最后直至对靶 1 进行溅射的功率密度递减至 $0.3\text{W}/\text{cm}^2$ 至 $1\text{W}/\text{cm}^2$ 之间的任意低功率密度,对靶 2 进行溅射的功率密度递增至 $4\text{W}/\text{cm}^2$ 至 $8\text{W}/\text{cm}^2$ 之间的任意高功率密度,执行共溅射的时间为 30 至 60 分钟,使得铜铟镓硒吸收层中的 Ga 浓度形成梯度,其在该吸收层与 Mo 背电极接触的一侧的浓度最高,在该吸收层的相对另一侧的浓度最低;

c) 进行退火处理:在真空室内以快速加热方式对铜铟镓硒吸收层进行退火处理,其温度为 400°C 至 600°C ,退火时间为 55 至 90 秒;

d) 在铜铟镓硒吸收层上制备 In_2Se_3 或 ZnS 缓冲层,其厚度为 80 至 120 纳米;

e) 在所述 In_2Se_3 或 ZnS 缓冲层上制备本征氧化锌高阻抗层,其厚度为 0.1 至 0.5 微米;

f) 在所述本征氧化锌高阻抗层上制备氧化铟锡薄膜低阻抗层,其厚度为 0.3 至 0.8 微米;

g) 在氧化铟锡薄膜低阻抗层上制备铝电极。

2. 如权利要求 1 所述的制备方法,其特征在于:所述铜铟镓硒吸收层的厚度为 1.5 微米至 2 微米。

3. 如权利要求 1 所述的制备方法,其特征在于:在执行步骤 b) 中,溅射腔体内的工作压力为 $1 \times 10^{-4}\text{Torr}$,衬底的温度保持在 350°C 至 450°C 之间的任意温度。

4. 如权利要求 1 所述的制备方法,其特征在于:在执行步骤 d) 中,利用真空磁控溅射法,采用 In_2Se_3 或 ZnS 合金靶,真空磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$ 并通入 Ar 气体,衬底的温度保持在室温。

5. 如权利要求 1 所述的制备方法,其特征在于:在执行步骤 e) 中,利用射频真空磁控溅射法,靶材为本征氧化锌,射频真空磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$,工作频率为 $400\text{K} \sim 2\text{MHz}$,并通入 Ar 气体,衬底的温度保持在室温。

6. 如权利要求 1 所述的制备方法,其特征在于:利用真空直流磁控溅射法,靶材为氧化铟锡 $\text{In}_2\text{O}_3:\text{SnO}_2$, $\text{In}_2\text{O}_3:\text{SnO}_2$ 的质量比为 9 : 1,真空直流磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$,并通入掺有 2% 至 5% O_2 的 Ar 气体,衬底的温度保持室温。

一种铜铟镓硒薄膜太阳能电池的制备方法

技术领域：

[0001] 本发明涉及太阳能电池领域，更具体的，涉及一种铜铟镓硒薄膜太阳能电池吸收层的制备方法。

背景技术：

[0002] 众所周知，铜铟镓硒化合物具有黄铜矿结构，可以制备在软性或刚性的衬底上作为太阳能发电的材料，由此制成的铜铟镓硒薄膜太阳能电池具有高稳定、低成本的优点。目前地球上可利用的能源日趋短少，而石化能源在使用过程中会排放碳、硫的氧化物造成空气污染并且加剧地球的温室效应，使地球的环境恶化气候异常，这已经是不争的事实了。因此开发无污染的可再生能源是当前世界各国的首要科研项目之一。而太阳能是无污染的能源，是可再生能源的最佳选择之一。太阳能的开发利用首要的是开发可以产生将太阳能高效率转换成电能的材料。

[0003] 铜铟镓硒化合物材料是具有黄铜矿结构的化合物半导体材料，其为直接带隙材料，能吸收波长范围较大的太阳光，且具有自调变自身组成以形成 p-n 结的特性，是公认的作为太阳能电池吸收层的最佳材料之一，例如铜铟镓二硒($\text{Cu}(\text{InGa})\text{Se}_2$)，简称 CIGS，为目前具有最高光吸收能力的半导体材料。由于 CIGS 的高光吸收率优势，使得 CIGS 吸收层的厚度在 $1\sim 2\mu\text{m}$ 即可，以一般粗略估算，在量产制造时，CIGS 材料的费用只需要 0.03 美元/瓦，因此极具竞争优势，有望使太阳能发电可以与传统的石化燃料发电成本相同甚至更低。因此如何制备低成本、高效率的铜铟镓硒太阳能薄膜电池，是目前最值得开发研究的课题之一。

[0004] CIGS 薄膜太阳能电池有两个优点：1 是光电转换层可以很薄，为几微米；二是其带隙（禁带宽度）可以通过 Ga（镓）在铜铟镓硒化合物的比例含量来调控。根据现有技术，Ga 和 In 的比例与带隙 (E_g) 存在如下的关系， $E_g(\text{eV})=1.02+0.67y+0.11y(y-1)$ ，其中 $y=\text{In}/(\text{Ga}+\text{In})$ 的原子含量比例。理论说明，单一带隙的太阳能电池不能最大限度的利用太阳能，也就是光子能量太小的产生不了电子-空穴对，能量太大的光子也只能激发一个电子-空穴对，多余的能量只能转化成不利于太阳能电池效率的热而已。因此从提高太阳能电池效率的角度考虑，希望太阳能电池有很多的带隙以尽量吸收更多的太阳能，而 CIGS 化合物的带隙的可调特性恰恰可以实现如此的设想。在制备 CIGS 薄膜时可以调节 Ga 的含量比例。增加 Ga 的比例，CIGS 化合物的禁带带隙会升高。

[0005] 现有文献中已记载制备 CIGS 薄膜的方法主要有：(1) 硒化法，(2) 叠层法，(3) 多源(二或三源)蒸发法，(4) 溅射法，(5) 沉积法，(6) 喷涂法，(7) 旋涂法，(8) 真空加热合成法等。而这 (1) 硒化法，(2) 叠层法，(3) 多源(二或三源)蒸发法，(4) 溅射法皆在某个工艺流程中需要对 CIGS 薄膜进行硫化或硒化处理，通过硫化或硒化处理可以使 S、Se 原子经扩散作用与 Cu-In-Ga 进行反应以生成 CuInGaSe 化合物，此过程称为硫化或硒化。

[0006] 硒化制备具有黄铜矿结构的薄膜太阳能电池的方法存在着一些缺点例如生产周期长、耗能多、消耗 Se 多、Se 的蒸汽有剧毒及 Se 的分布不均匀，Se 存在梯度等等。

[0007] 另外对于调控 Ga 的梯度分布工艺,上述的各种工艺方法比较难以一步到位的实现。例如美国的 NREL 实验室开发的三阶段共蒸发法,其实现 Ga 呈上述的带隙梯度 A 或 V 字形带隙梯度是在三个阶段不同的元素参与蒸发反应,工艺非常复杂且需要实时控制精准方能实现。此种方法虽然可以制备高转换效率的太阳能薄膜电池,但是不利于低成本、大面积、规模化的生产。

发明内容

[0008] 本发明提供一种铜铟镓硒薄膜太阳能电池的制备方法,其包括:

[0009] a) 在衬底上制备钼背电极;

[0010] b) 在该钼背电极上制备铜铟镓硒吸收层:利用真空磁控溅射法,采用 $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ 合金靶进行溅射,设 $x=0$ 的 CuGaSe_2 合金靶为靶 1,设 $x=0.8$ 至 0.6 的 $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ 合金靶为靶 2,首先以高功率密度 $4\text{W}/\text{cm}^2$ 至 $8\text{W}/\text{cm}^2$ 之间的任意高功率密度对靶 1 先溅射 2 至 4 分钟,接着再对靶 1 和靶 2 进行共溅射,此时对靶 2 进行溅射的初始功率密度为 $0.3\text{W}/\text{cm}^2$ 至 $1\text{W}/\text{cm}^2$ 之间任意的低功率密度,而对靶 1 进行溅射的高功率密度设置成在工作中连续递减,在对靶 1 和靶 2 进行共溅射的状态下,当对靶 1 进行溅射的功率密度连续递减时,与此同时对靶 2 进行溅射的功率密度则为连续递增,最后直至对靶 1 进行溅射的功率密度递减至 $0.3\text{W}/\text{cm}^2$ 至 $1\text{W}/\text{cm}^2$ 之间的任意低功率密度,对靶 2 进行溅射的功率密度递增至 $4\text{W}/\text{cm}^2$ 至 $8\text{W}/\text{cm}^2$ 之间的任意高功率密度,执行共溅射的时间为 30-60 分钟,使得铜铟镓硒吸收层中的 Ga 浓度形成梯度,其在该吸收层与 Mo 背电极接触的一侧的浓度最高,在该吸收层的相对另一侧的浓度最低;

[0011] c) 进行退火处理:在真空室内以快速加热方式对铜铟镓硒吸收层进行退火处理,其温度为 400°C 至 600°C ,退火时间为 55 至 90 秒;

[0012] d) 在铜铟镓硒吸收层上制备 In_2Se_3 或 ZnS 缓冲层,其厚度为 80 至 120 纳米;

[0013] e) 在所述 In_2Se_3 或 ZnS 缓冲层上制备本征氧化锌高阻抗层,其厚度为 0.1 至 0.5 微米;

[0014] f) 在所述本征氧化锌高阻抗层上制备氧化铟锡薄膜低阻抗层,其厚度为 0.3 至 0.8 微米;

[0015] g) 在氧化铟锡薄膜低阻抗层上制备铝电极。

[0016] 其中:所述铜铟镓硒吸收层的厚度为 1.5 微米至 2 微米。

[0017] 其中:在执行步骤 b) 中,溅射腔体内的工作压力为 $1 \times 10^{-4}\text{Torr}$,衬底的温度保持在 350°C 至 450°C 之间的任意温度。

[0018] 其中:在执行步骤 d) 中,利用真空磁控溅射法,采用 In_2Se_3 或 ZnS 合金靶,真空磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$ 并通入 Ar 气体,衬底的温度保持在室温。

[0019] 其中:在执行步骤 e) 中,利用射频真空磁控溅射法,靶材为本征氧化锌,射频真空磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$,工作频率为 $400\text{K} \sim 2\text{MHz}$,并通入 Ar 气体,衬底的温度保持在室温。

[0020] 其中:利用真空直流磁控溅射法,靶材为氧化铟锡 $\text{In}_2\text{O}_3:\text{SnO}_2$, $\text{In}_2\text{O}_3:\text{SnO}_2$ 的质量比为 9:1,真空直流磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$,并通入掺有 2% 至 5% O_2 的 Ar 气体,衬底的温度保持室温。

[0021] 根据本发明的方法,无硒化工艺流程及无镉的 In_2Se_3 或 ZnS 缓冲层,不但可以避免 H_2Se 、 H_2S 的有毒气体,并且使用无镉的化合物,既符合环保又可降低成本,并且使得生产工艺设备简单能源消耗小,生产周期短等优势。

[0022] 本发明与现有技术相比有以下优点:本发明所有的工艺皆为干式工艺流程,工艺过程不使用化学溶剂与溶液。太阳能电池的吸收层制备采用一步操作即可得到稳定结晶的吸收层,不再需要对吸收层进行硒化或硫化的工业程序,大大缩短了生产周期,减少了生产设备,也避免了生产过程中的环境污染和潜在的危险。本发明的工艺步骤简化,能源消耗小,因此降低了生产成本。

附图说明

[0023] 图 1 是本发明的制备铜镓硒薄膜太阳能电池吸收层的方法的流程图;

[0024] 图 2 是对根据本发明的方法制备的太阳能电池吸收层所做的二次离子质谱 (SIMS) 分析曲线图。

具体实施方式

[0025] 图 1 是本发明的制备铜镓硒薄膜太阳能电池吸收层的方法的流程图,如图所示:

[0026] 首先在衬底上制备背电极。所述衬底可以选择钠钙玻璃或者不锈钢薄片,一般选用 1-3mm 厚的钠钙玻璃或者 0.2mm 厚不锈钢薄片。采用磁控溅射法沉积 0.8 微米厚的钼 (Mo) 金属作为背电极。

[0027] 接着在背电极上制备吸收层:本发明采用双靶共溅射来制备吸收层,该靶为 $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ 合金靶,为了说明方便,可以设 $x=0$ 的 CuGaSe_2 合金靶为靶 1,设 $x=0.8$ 至 0.6 的 $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ 合金靶为靶 2,例如 $\text{Cu}(\text{In}_{0.7}\text{Ga}_{0.3})\text{Se}_2$ 合金靶 2。首先以高功率密度 $4\text{W}/\text{cm}^2$ 至 $8\text{W}/\text{cm}^2$ 之间的任意高功率密度对靶 1 先溅射 2 至 4 分钟,接着再对靶 1 和靶 2 进行共溅射,此时对靶 2 进行溅射的初始功率密度为 $0.3\text{W}/\text{cm}^2$ 至 $1\text{W}/\text{cm}^2$ 之间任意的低功率密度,而对靶 1 进行溅射的高功率密度设置成在工作中连续递减。由于此时对靶 1 和靶 2 进行共溅射,而且为了确保铜镓硒吸收层中的 Ga 浓度形成梯度,将对靶 1 和靶 2 进行溅射的功率密度设计成为:当对靶 1 进行溅射的功率密度连续递减时,与此同时对靶 2 进行溅射的功率密度则为连续递增,最后直至对靶 1 进行溅射的功率密度递减至 $0.3\text{W}/\text{cm}^2$ 至 $1\text{W}/\text{cm}^2$ 之间的任意低功率密度,对靶 2 进行溅射的功率密度递增至 $4\text{W}/\text{cm}^2$ 至 $8\text{W}/\text{cm}^2$ 之间的任意高功率密度。执行共溅射的时间为 30 至 60 分钟,使得在钼背电极上沉积铜镓硒吸收层的厚度为 1.5 微米至 2 微米。溅射腔体内的工作压力为 $1 \times 10^{-4}\text{Torr}$,衬底的温度保持在 350°C 至 450°C 之间的任意温度。根据该工艺,使得铜镓硒吸收层中的 Ga 浓度形成梯度,其在该吸收层与 Mo 背电极接触的一侧的浓度最高,在该吸收层的相对另一侧的浓度最低。

[0028] 随后进行退火处理:在真空室内以快速加热方式对铜镓硒吸收层进行退火处理,其温度为 400°C 至 600°C ,退火时间为 55 至 90 秒。在退火过程中不需要通入任何气体。经过退火处理的铜镓硒吸收层具有黄铜矿结构,并通过热能进行局部离子扩散,提高结晶状态,提高太阳能电池主吸收层的光伏发电效率。

[0029] 再接着在吸收层上制备缓冲层:利用真空磁控溅射法,采用 In_2Se_3 或 ZnS 合金靶,

溅射沉积 In_2Se_3 或 ZnS 缓冲层,真空磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$ 并通入 Ar 气体,衬底的温度保持在室温。所述 In_2Se_3 或 ZnS 缓冲层的沉积厚度为 80 至 120 纳米。

[0030] 紧接着在缓冲层上制备本征氧化锌高阻抗层:利用射频真空磁控溅射法,靶材为本征氧化锌(ZnO),射频真空磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$,工作频率为 $400\text{K} \sim 2\text{MHz}$,并通入 Ar 气体,衬底的温度保持在室温。所述本征氧化锌高阻抗层的沉积厚度为 0.1 至 0.5 微米。

[0031] 紧接着在本征氧化锌高阻抗层上制备氧化铟锡($\text{In}_2\text{O}_3:\text{SnO}_2$)薄膜低阻抗层:利用真空直流磁控溅射法,靶材为氧化铟锡($\text{In}_2\text{O}_3:\text{SnO}_2$), $\text{In}_2\text{O}_3:\text{SnO}_2$ 的质量比为 9 : 1,真空直流磁控溅射的工作压力为 $1-5 \times 10^{-3}\text{Torr}$,并通入掺有 2% 至 5% O_2 的 Ar 气体,衬底的温度保持室温。所述氧化铟锡薄膜低阻抗层的沉积厚度为 0.3 至 0.8 微米。

[0032] 最后在氧化铟锡薄膜低阻抗层上制备铝电极:利用 Al 靶材,通过溅射法制备 Al 电极,最终得到具有 Ga 的浓度梯度的铜铟镓硒薄膜太阳能电池。

[0033] 图 2 是对根据本发明的方法制备的太阳能电池吸收层所做的二次离子质谱(SIMS)分析曲线图。 Ga 的浓度在 Mo 背电极侧最高,然后到 CIGS 薄膜表面递减,表明具有梯度分布的禁带宽度。

[0034] 本发明与现有技术相比有以下优点:本发明所有的工艺皆为干式工艺流程,工艺过程不使用化学溶剂与溶液。太阳能电池的吸收层制备采用一步操作即可得到稳定结晶的吸收层,不再需要对吸收层进行硒化或硫化的工艺程序,大大缩短了生产周期,减少了生产设备,也避免了生产过程中的环境污染和潜在的危险。本发明的工艺步骤简化,能源消耗小,因此降低了生产成本。

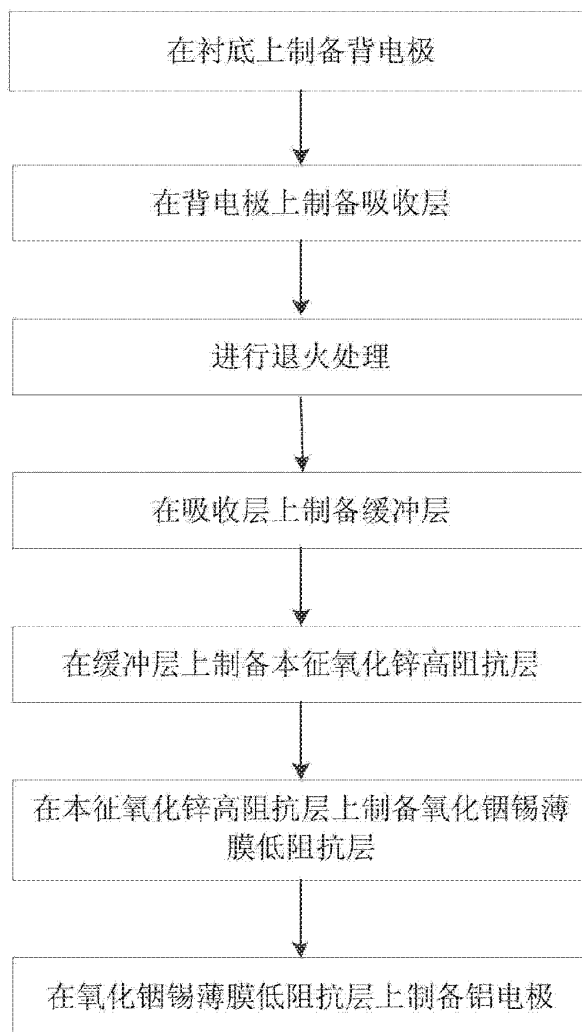


图 1

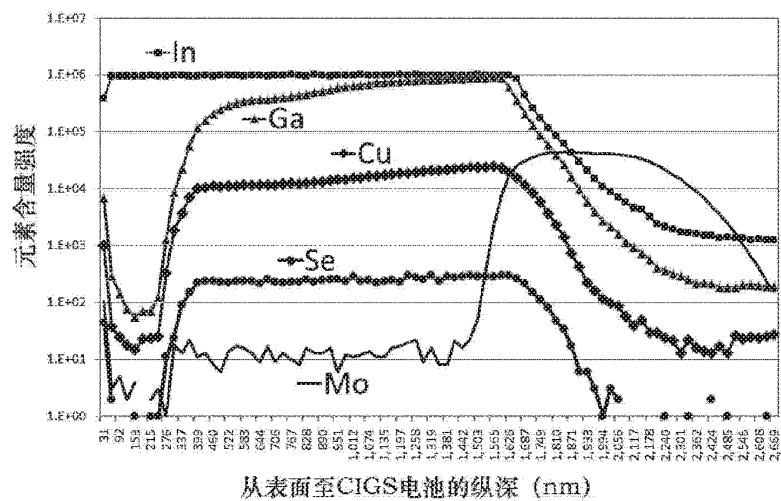


图 2

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)	Docket Number (Optional) 131815-255190_P167C2DC
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Application Number 16/877,255	Filed May 18, 2020
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For **SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY**

Art Unit 1757	Examiner Unassigned
-------------------------	-------------------------------

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above-identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

	<u>Fee</u>	<u>Small Entity Fee</u>	<u>Micro Entity Fee</u>	
☐ One month (37 CFR 1.17(a)(1))	\$220	\$110	\$55	\$ _____
☐ Two months (37 CFR 1.17(a)(2))	\$640	\$320	\$160	\$ _____
☒ Three months (37 CFR 1.17(a)(3))	\$1,480	\$740	\$370	\$ 1,480
☐ Four months (37 CFR 1.17(a)(4))	\$2,320	\$1,160	\$580	\$ _____
☐ Five months (37 CFR 1.17(a)(5))	\$3,160	\$1,580	\$790	\$ _____

- ☐ Applicant asserts small entity status. See 37 CFR 1.27.
- ☐ Applicant certifies micro entity status. See 37 CFR 1.29.
Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously.
- ☐ A check in the amount of the fee is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The Director has already been authorized to charge fees in this application to a Deposit Account.
- ☒ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to
Deposit Account Number 500393.
- ☒ Payment made via EFS-Web.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

- ☐ applicant.
- ☒ attorney or agent of record. Registration number 61,080
- ☐ attorney or agent acting under 37 CFR 1.34. Registration number _____

<u>/Justin K. Brask/</u> Signature	<u>October 27, 2020</u> Date
<u>Justin K. Brask</u> Typed or printed name	<u>503-222-9981</u> Telephone Number

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms if more than one signature is required, see below*.

☒ * Total of <u>1</u> forms are submitted.
--

This collection of information is required by 37 CFR 1.136(a). 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 6 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: Mail Stop PCT, 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 disclosure of these records is required by the Freedom of Information Act.
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 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.

Electronic Patent Application Fee Transmittal				
Application Number:		16877255		
Filing Date:		18-May-2020		
Title of Invention:		SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		
First Named Inventor/Applicant Name:		David D. Smith		
Filer:		Justin K. Brask/Blanche Niksich		
Attorney Docket Number:		131815-255190_P167C2DC		
Filed as Large Entity				
Filing Fees for Utility under 35 USC 111(a)				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
UTILITY APPLICATION FILING	1011	1	320	320
UTILITY SEARCH FEE	1111	1	700	700
UTILITY EXAMINATION FEE	1311	1	800	800
Pages:				
Claims:				
Miscellaneous-Filing:				
LATE FILING FEE FOR OATH OR DECLARATION	1051	1	160	160
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
PETITION FEE- 37 CFR 1.17(H) (GROUP III)	1464	1	140	140
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 3 months with \$0 paid	1253	1	1480	1480
Miscellaneous:				
Total in USD (\$)				3600

Electronic Acknowledgement Receipt	
EFS ID:	40960237
Application Number:	16877255
International Application Number:	
Confirmation Number:	2637
Title of Invention:	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY
First Named Inventor/Applicant Name:	David D. Smith
Customer Number:	149776
Filer:	Justin K. Brask/Gigi Hoover
Filer Authorized By:	Justin K. Brask
Attorney Docket Number:	131815-255190_P167C2DC
Receipt Date:	27-OCT-2020
Filing Date:	18-MAY-2020
Time Stamp:	19:28:52
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$3600
RAM confirmation Number	E20200QJ32011459
Deposit Account	500393
Authorized User	Gigi Hoover
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)					
37 CFR 1.20 (Post Issuance fees)					
37 CFR 1.21 (Miscellaneous fees and charges)					
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		P167C2DC_Resp_to_NOMP_A mendment_Petition_10272020 .pdf	468546	yes	61
			8a6aa991bbba53774b0c8de88b59bdaca0a28ff2		
	Multipart Description/PDF files in .zip description				
	Document Description		Start		End
	Specification		14		61
	Drawings-only black and white line drawings		13		13
	A petition from Applicant to accept Color Drawings or Color Photographs		1		12
Warnings:					
Information:					
2		7923P167C2DC_IDS.pdf	183340	yes	3
			80c2f00b73ac7bf87a918ad624e81def183a985a		
	Multipart Description/PDF files in .zip description				
	Document Description		Start		End
	Information Disclosure Statement (IDS) Form (SB08)		2		3
	Transmittal Letter		1		1
Warnings:					
Information:					
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Information:					

4	Non Patent Literature	2_7923P167PCT_ISRWO.pdf	492234	no	11
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Information:					
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Warnings:					
Information:					
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Warnings:					
Information:					
8	Non Patent Literature	7_NPL_PVI8_Methods_Of_Emitter_Formation_C-Si_Solar_Cells_ECN.pdf	917097	no	12
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Warnings:					
Information:					
9	Non Patent Literature	6_7923P167EP_Search-Report.pdf	1085377	no	15
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Warnings:					
Information:					
10	Non Patent Literature	8_CN_OA.pdf	1615611	no	14
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11	Non Patent Literature	9_FAI_PIC.pdf	308213	no	6
			971d534462c599521496afb9ca6e0089f0525706		
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12	Non Patent Literature	10_P167CN_Second_OA.pdf	1813959	no	12
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Information:					
13	Non Patent Literature	11_P167EP_Exam_Report.PDF	465647	no	6
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Information:					
14	Non Patent Literature	12_7923P167C2D_FAI.pdf	285936	no	5
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15	Non Patent Literature	13_OA_CN.pdf	1597536	no	9
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16	Non Patent Literature	14_7923P167C2DC_OA_CN.pdf	1804832	no	12
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17	Foreign Reference	15_JP2011166021A.pdf	498057	no	13
			5a2e599b1d9103ecf0719b290cc15793b28a24c8		
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18	Foreign Reference	16_CN102694077.pdf	1383244	no	20
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19	Extension of Time	P167C2DC_3mo_EOT_10272020.pdf	125426	no	2
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Warnings:					
Information:					
20	Fee Worksheet (SB06)	fee-info.pdf	41223	no	2
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Warnings:					
Information:					
Total Files Size (in bytes):			14526558		
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. <u>New Applications Under 35 U.S.C. 111</u> 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. <u>National Stage of an International Application under 35 U.S.C. 371</u> 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. <u>New International Application Filed with the USPTO as a Receiving Office</u> 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.					

NEW SHEET

Example Process	Temp	Surface Dopant Conc.	Gettering Location	Surface Passivation	Lifetime	Efficiency
A	≤ 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	non-poly	2 fA/cm^2	$\sim 3 \text{ msec}$	Baseline
B	≤ 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	non-poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline
C	≤ 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	poly	2 fA/cm^2	$\sim 10 \text{ msec}$	+0.5 % abs.
D	≤ 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline

Table 1. Example Processes for Solar Cell Fabrication

FIG. 11

MARKED UP VERSION OF SUBSTITUTE SPECIFICATION

SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR
EFFICIENCY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. Patent Application No. 16/228,165, filed on December 20, 2018, which is a divisional of U.S. Patent Application No. 15/876,927, filed on January 22, 2018, now U.S. Patent No. 10,170,642, issued on January 1, 2019, which is a continuation of U.S. Patent Application No. 15/213,273, filed on July 18, 2016, now U.S. Patent No. 9,899,542, issued on February 20, 2018, which is a continuation of U.S. Patent Application No. 14/579,935, filed on December 22, 2014, now U.S. Patent No. 9,520,507, issued on December 13, 2016, the entire contents of which are hereby incorporated by reference herein.

BACKGROUND

[0002] Photovoltaic (PV) cells, commonly known as solar cells, are devices for conversion of solar radiation into electrical energy. Generally, solar radiation impinging on the surface of, and entering into, the substrate of a solar cell creates electron and hole pairs in the bulk of the substrate. The electron and hole pairs migrate to p-doped and n-doped regions in the substrate, thereby creating a voltage differential between the doped regions. The doped regions are connected to the conductive regions on the solar cell to direct an electrical current from the cell to an external circuit. When PV cells are combined in an array such as a PV module, the electrical energy collect from all of the PV cells can be combined in series and parallel arrangements to provide power with a certain voltage and current.

[0003] Efficiency is an important characteristic of a solar cell as it is directly related to the solar cell's capability to generate power. Accordingly, techniques for improving the fabrication process, reducing the cost of

manufacturing and increasing the efficiency of solar cells are generally desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0004] [0005] Figure 1 illustrates a flow chart representation of an example method for fabricating of a solar cell, according to some embodiments.

[0005] [0006] Figures 2-4 illustrate cross-sectional views of example solar cells during the fabrication process of Figure 1, according to some embodiments.

[0006] [0007] Figure 5 illustrates a cross-sectional view of an example solar cell, according to some embodiments.

[0007] [0008] Figure 6 illustrates a cross-sectional view of another example solar cell, according to some embodiments.

[0008] [0009] Figure 7 illustrates a cross-sectional view of still another example solar cell, according to some embodiments.

[0009] [0010] Figure 8 illustrates a graph of example surface passivation measurements, according to some embodiments.

[0010] [0011] Figure 9 illustrates a graph of example 1/lifetime measurements, according to some embodiments.

[0011] [0012] Figure 10 illustrates a graph of example efficiency measurements, according to some embodiments.

[0013] Figure 11 illustrates example processes for solar cell fabrication.

DETAILED DESCRIPTION

~~[0013]~~ [0014] The following detailed description is merely illustrative in nature and is not intended to limit the embodiments of the subject matter of the application or uses of such embodiments. As used herein, the word “exemplary” means “serving as an example, instance, or illustration.” Any implementation described herein as exemplary is not necessarily to be construed as preferred or advantageous over other implementations. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

~~[0014]~~ [0015] This specification includes references to “one embodiment” or “an embodiment.” The appearances of the phrases “in one embodiment” or “in an embodiment” do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

~~[0015]~~ [0016] Terminology. The following paragraphs provide definitions and/or context for terms found in this disclosure (including the appended claims):

~~[0016]~~ [0017] “Comprising.” This term is open-ended. As used in the appended claims, this term does not foreclose additional structure or steps.

~~[0017]~~ [0018] “Configured To.” Various units or components may be described or claimed as “configured to” perform a task or tasks. In such contexts, “configured to” is used to connote structure by indicating that the units/components include structure that performs those task or tasks during operation. As such, the unit/component can be said to be configured to perform the task even when the specified unit/component is not currently operational (e.g., is not on/active). Reciting that a unit/circuit/component is “configured to” perform one or more tasks is expressly intended not to invoke 35 U.S.C. §112, sixth paragraph, for that unit/component.

~~[0018]~~ [0019] “First,” “Second,” etc. As used herein, these terms are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.). For example, reference to a “first” emitter region does not necessarily imply that this emitter region is the first emitter region in a sequence; instead the term “first” is used to differentiate this emitter region from another emitter region (e.g., a “second” emitter region). In an embodiment, an emitter region can be a doped region of a solar cell for collecting positive and negative charge carriers. In an example, the emitter region can be a doped polysilicon region. In one example, the emitter region can be a P-type doped polysilicon region or an N-type doped polysilicon region.

~~[0019]~~ [0020] “Based On.” As used herein, this term is used to describe one or more factors that affect a determination. This term does not foreclose additional factors that may affect a determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase “determine A based on B.” While B may be a factor that affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.

~~[0020]~~ [0021] “Coupled” – The following description refers to elements or nodes or features being “coupled” together. As used herein, unless expressly stated otherwise, “coupled” means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically.

~~[0021]~~ [0022] In addition, certain terminology may also be used in the following description for the purpose of reference only, and thus are not intended to be limiting. For example, terms such as “upper”, “lower”, “above”, and “below” refer to directions in the drawings to which reference is made. Terms such as “front”, “back”, “rear”, “side”, “outboard”, and “inboard” describe the orientation and/or location of portions of the component within a consistent but arbitrary frame of reference which is made

clear by reference to the text and the associated drawings describing the component under discussion. Such terminology may include the words specifically mentioned above, derivatives thereof, and words of similar import. ~~[0022]~~ **[0023]** In the following description, numerous specific details are set forth, such as specific operations, in order to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to one skilled in the art that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known techniques are not described in detail in order to not unnecessarily obscure embodiments of the present disclosure.

~~[0023]~~ **[0024]** This specification first describes solar cell fabrication techniques to improve solar cell lifetime, passivation and/or efficiency followed by a description of example solar cells fabricated according to the disclosed techniques. Various embodiments are provided throughout followed by example results from the disclosed techniques.

~~[0024]~~ **[0025]** Turning now to Figure 1, a method for fabricating a solar cell is shown, according to some embodiments. In various embodiments, the method of Figure 1 can include additional (or fewer) blocks than illustrated. For example, in some embodiments, the silicon region formed at block 102 can be heated to form a polysilicon region after step 102 but before to the heating step of block 106.

~~[0025]~~ **[0026]** At 100, a dielectric can be formed on a silicon substrate of a solar cell. In some embodiments, the silicon substrate can be cleaned, polished, planarized, and/or thinned or otherwise processed prior to the formation of the dielectric region. In an embodiment, the silicon substrate can be single-crystalline or a multicrystalline silicon substrate. In an embodiment, the silicon substrate can be a N-type silicon substrate. In an embodiment, the dielectric can be a tunnel oxide. In one embodiment, the dielectric can be silicon dioxide. In an embodiment, the dielectric region can be grown and/or formed through a thermal process.

[0026] [0027] At 102, an emitter region can be formed over the dielectric region. In an embodiment, the emitter region can be an amorphous silicon region. In some embodiments, the amorphous silicon region can be grown over the dielectric region. In an embodiment, the emitter region can be polysilicon. In an embodiment, the emitter region can be grown and/or formed through a thermal process. In an example, an amorphous silicon region can be formed over the dielectric region and heated to form a polysilicon region.

[0027] [0028] An emitter dopant region can be deposited over the emitter region through a deposition process. The emitter dopant region can comprise a dopant, such as a positive-type doping material such as boron or a negative-type doping material such as phosphorous.

[0028] [0029] Although the dielectric region and/or the emitter region are described as being grown by a thermal process or deposited through conventional deposition process, respectively, as with any other formation, deposition, or growth process step described or recited here, each layer or substance can be formed using any appropriate process. For example, a chemical vapor deposition (CVD) process, low-pressure CVD (LPCVD), atmospheric pressure CVD (APCVD), plasma-enhanced CVD (PECVD), thermal growth, sputtering, as well as any other desired technique can be used where formation is described. Thus, and similarly, the emitter dopant region can be formed on the substrate by a deposition technique, implant process, sputter, or print process, such as inkjet printing or screen printing.

[0029] [0030] In an embodiment, a heating process can be performed to drive dopants from the emitter dopant region to the emitter region. In one example, the heating process can drive dopants from the emitter dopant region to a polysilicon region to form a doped polysilicon region. In an embodiment, the doped polysilicon region can be doped with a P-type dopant such as boron or an N-type dopant such as phosphorus. In one example, the doped polysilicon regions can be formed in alternating P-type and N-type regions. In some embodiments, the heating to drive dopants from the emitter dopant region to

the emitter region, can be performed at a temperature below 900 degrees Celsius.

[0030] [0031] At 104, a dopant region can be formed over a surface of the silicon substrate. In an embodiment, the dopant region can be grown and/or formed through a thermal process. In one example, the dopant region can be formed over a surface, e.g., on the front side of a solar cell, and subsequently a heating process can be performed to drive dopants into a portion of the silicon substrate. In an embodiment, the portion of the silicon substrate can have a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ after the heating process as discussed in block 106.

[0034] [0032] In one embodiment, the dopant region can be an N-type dopant, e.g., phosphorus. In an embodiment, the surface of the silicon substrate over which the dopant region is formed can be a front side, back side, or both on the front and back sides of the solar cell. Figure 2 shows an example solar cell having the dielectric region, emitter region and dopant region described above.

[0032] [0033] Although the dopant region is described as being grown by a thermal process or deposited through conventional deposition process, respectively, as with any other formation, deposition, or growth process step described or recited here, each layer or substance can be formed using any appropriate process. For example, a chemical vapor deposition (CVD) process, low-pressure CVD (LPCVD), atmospheric pressure CVD (APCVD), plasma-enhanced CVD (PECVD), thermal growth, sputtering, as well as any other desired technique can be used where formation is described.

[0033] [0034] Figure 2 illustrates an example solar cell after forming the dielectric region, emitter region, and dopant region, according to some embodiments. In an embodiment, a dielectric region 210 can be formed over a silicon substrate 202 of the solar cell 200. In an embodiment, the dielectric region 210 can be a tunnel oxide. In one example, the dielectric region 210 can be silicon dioxide. In an embodiment, an emitter region 212 can be formed on the dielectric region 210. In an embodiment and as noted above, the emitter region 212 can be amorphous silicon or polysilicon. In an

embodiment, the emitter region 212 can be a doped polysilicon. In an example, the doped polysilicon can be N-type doped or P-type doped polysilicon.

[0034] [0035] In an embodiment, a dopant region 216 can be formed on a surface 204 of silicon substrate 202. In an embodiment, the dopant region 216 can be formed to dope the surface 204 (e.g., at block 106 below) to repel charge carriers and prevent and/or reduce recombination at the surface 204 of the solar cell 200. In an example, the surface 204, can be on a front side and/or a back side of the solar cell. In one example, the dopant region 216 can be a N-type dopant region, such as phosphorus. In an embodiment, the dopant region 216 can have positive or negative type dopants 222.

[0035] [0036] In an embodiment, the silicon substrate 202 can have contaminants and/or impurities 220, for example metal contaminants and/or metal impurities, such as iron, nickel and/or chromium among others. Metal impurities can be detrimental to the electrical conduction of the solar cell as these impurities can be sources of recombination, resulting in poor lifetime, surface passivation and/or lower solar cell efficiency. In an embodiment, the impurities 220 can be located at or near a surface 204 of the silicon substrate 202. In an embodiment, the impurities 220 can be located within the silicon substrate 202 as shown. As referred throughout, contaminants and/or impurities can be used interchangeably.

[0036] [0037] The emitter regions 212, e.g., polysilicon regions, can be a good sink and/or trap for the metal impurities 220 discussed above. A gettering process can be used to trap the metal impurities 220 in the emitter regions 212, reducing recombination within the silicon substrate 202 and improving overall solar cell lifetime. Oxides and/or tunnel oxides, such as the dielectric region 210 of Figure 2, can be barriers to gettering of the metal impurities 220 to emitter regions 212. In one example, heating at temperature at 900 degrees Celsius or below can be insufficient to diffuse metal impurities through a tunnel oxide and into a polysilicon region. Thus, in an embodiment, heating at temperatures above 900 degrees Celsius can include gettering metal

impurities 220 through the dielectric region 210, e.g., tunnel oxide, to into the emitter region 212, e.g., polysilicon regions, as discussed in detail at 106 of Figure 1 below.

[0037] [0038] At 106, the solar cell can be heated at a temperature above 900 degrees Celsius. In an embodiment, the heating can drive dopants from the dopant region to a portion of the silicon substrate. In one embodiment, the heating can include performing an annealing process on the silicon substrate. In an example, the heating can drive dopants to the portion of the silicon substrate located above the surface, as shown in Figure 3. In some embodiments, the surface can be on the front side, back side or both on the front and back side of the solar cell. In an embodiment, the heating can include gettering contaminants, e.g. metal impurities and/or metal contaminants, from the substrate to the emitter region. In an example, the metal impurities and/or metal contaminants can be iron, nickel and/or chromium among others.

[0038] [0039] In one example, the heating can include placing the solar cell in thermal tool, e.g., a thermal furnace or oven among others, and raising the temperature in the thermal tool to 975 degrees Celsius or above.

[0039] [0040] In an embodiment, the heating can be the last heating step in the solar cell fabrication process. In one embodiment, the heating can be the only heating step in the fabrication process. In some embodiments, at least one other heating step can be performed before the heating process of block 106. In one example, the other heating process, aside from the heating process of block 106, can include heating the solar cell to temperature below 900 degrees Celsius. In an example, the heating process below 900 degrees Celsius can be performed before the heating process at 106. In an embodiment, the heating performed at 106 can be performed at the highest temperature among other heating steps performed in the solar cell fabrication process. Figure 3 illustrates the heating process described above.

[0040] [0041] Figure 3 illustrates heating the solar cell of Figure 2, according to some embodiments. In an embodiment, the heating 230 can include heating

the solar cell 200 above 900 degrees Celsius. In an example, the heating can include placing the solar cell 200 into a thermal tool, e.g., thermal furnace or oven among others, and raising the temperature within the thermal tool to 975 degrees Celsius or higher. In an embodiment, the heating 230 can drive 234 the dopants 222 from the dopant region 216 to a portion 206 of the silicon substrate 202. In an example, the dopant concentration of the portion 206 of the silicon substrate 202 can be approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ after the heating. In an embodiment, the portion 206 of the silicon substrate 202 can be above, as shown, the surface 204 of the silicon substrate 202. In an embodiment, the heating 230 can getter 232 contaminants 220 from, or nearby, the surface 204 of the silicon substrate 202 and/or from within the silicon substrate 202 to the emitter region 212. In an embodiment, the heating 230 can getter 232 the containments 220 through the dielectric region 210 to the emitter region 212.

[0041] [0042] At 108, a metal contact can be formed over the silicon substrate. In an embodiment, the metal contact can be formed on the emitter region. In some embodiments, the metal contact can be formed by a metallization process. In one example, the metallization process can include plating and/or electroplating the metal contact to the emitter region. In some embodiments, the metal contact can be formed by printing and/or foil-based metallization techniques. Figure 4 illustrates an example silicon substrate after to forming the metal contact. Also Figure 4 illustrates a single metal contact, for example, which can be on a front side or back side of the solar cell. In an embodiment, multiple metal contacts can exist. In an example, positive and negative metal contacts can be formed in an interdigitated pattern.

[0042] [0043] With reference to Figure 4, the solar cell of Figure 3 is shown after forming a metal contact, according to some embodiments. In an embodiment, the metal contact 242 can be formed on the emitter region 212, e.g. over the silicon substrate 202. In an example, the metal contact 242 can be formed by an electroplating process, printing process or a foil-based metallization process among others. In an embodiment, the metal contact 242

can be a positive or negative metal contact. As shown in Figure 4 a single metal contact is illustrated for example, which can be on a front side or back side of the solar cell. In an example, multiple metal contacts, e.g. some positive and others negative, can exist. In one embodiment, the silicon substrate 202 can have some impurities 221 remaining after the heating 230 of Figure 3.

[0043] [0044] Figure 5 illustrates a cross-section of a portion of a solar cell formed from the method of Figures 1-4, according to some embodiments. The solar cell 300 can have a front side 301 which faces the sun during normal operation and a back side 303 opposite the front side 301. The solar cell 300 can include a silicon substrate 302. In an embodiment, the silicon substrate 302 can be an N-type silicon substrate. In an embodiment, a portion 306 of the silicon substrate 302 can have a doping concentration 322 of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$.

[0044] [0045] The solar cell 300 can have a dielectric region 310 formed over the silicon substrate 302. In an embodiment, the dielectric 310 can be a tunnel oxide. In some embodiments, the dielectric region 310 can be silicon dioxide. In an embodiment, the solar cell 300 can have first and second emitter regions 312, 314. In an example, the first and second emitter regions 312, 314 can be P-type and N-type doped polysilicon regions, respectively. In an example, impurities and/or contaminants 320, e.g. metal impurities 320 and/or metal contaminants, can be located in the first and second emitter regions 312, 314 as shown. In one embodiment, the silicon substrate 302 can have some impurities 321 remaining after the gettering process.

[0045] [0046] In an embodiment, the solar cell 300 can have first and second metal contacts 342, 344 formed on the first and second emitter regions 312, 314, respectively. In some embodiments, a trench region 305 can be formed, which can separate the first and second emitter regions 312, 314. In an embodiment, the solar cell 300 can have a textured surface 304 on the front side 301. In an example, the textured surface 304 can be a surface which can provide additional light absorption. In an embodiment, the portion 306 of the

silicon substrate 302 can be formed above a textured surface 304 as shown. In some embodiments, the trench region 305 can also be textured, similar to the textured surface 304, for additional light absorption from the back side 303 of the solar cell 300. In some embodiments, an anti-reflective region (ARC) 318 can be formed over the textured surface 304 of the solar cell 300. In some embodiments, the anti-reflective region 318 can be silicon nitride.

[0046] [0047] In an embodiment, the solar cell 300 can be a back contact solar cell, for example, as shown in Figures 5 and 7.

[0047] [0048] With reference to Figure 6, a front contact solar cell formed from the method of Figures 1-4 is shown, according to some embodiments. The solar cell 400 can have a front side 401 which faces the sun during normal operation and a back side 403 opposite the front side 401. The solar cell 400 can include a silicon substrate 402. In an embodiment, the silicon substrate 402 can be a N-type silicon substrate. In an embodiment, a portion 406 of the silicon substrate 402 can have a doping concentration 422 of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$.

[0048] [0049] The solar cell 400 can have a dielectric 410 formed over the silicon substrate 402. In an embodiment, the dielectric 410 can be a tunnel oxide. In some embodiments, the dielectric 410 can be silicon dioxide. In an embodiment, the solar cell 400 can have first and second emitter regions 412, 414. In some embodiments, the first emitter region 412 can be formed on the back side 403 of the solar cell 400 and the second emitter region 414 can be formed on the front side 401 of the solar cell 400. In an example, the first and second emitter regions 412, 414 can be P-type and/or N-type doped polysilicon regions.

[0049] [0050] In an embodiment, the solar cell 400 can have first and second metal contacts 442, 444 formed on the first and second emitter regions 412, 414, respectively. In an embodiment, the solar cell 400 can have a textured surface 404 on the front side 401. In an example, the textured surface 404 can be a surface which can provide additional light absorption. In an embodiment, the portion 406 of the silicon substrate 402 can be above a textured surface

404 as shown. In some embodiments, an anti-reflective region (ARC) 418 can be formed over the textured surface 404 of the solar cell 400. In some embodiments, the anti-reflective region 418 can be silicon nitride.

[0050] [0051] In an example, impurities and/or contaminants 420, e.g. metal impurities and/or contaminants, can be located in the first and second emitter regions 412, 414. In one embodiment, the silicon substrate 402 can have some impurities 421 remaining after the gettering process.

[0051] [0052] Figure 7 illustrates still another solar cell formed from the method of Figures 1-4, according to some embodiments. The solar cell 500 can have a front side 501 which faces the sun during normal operation and a back side 503 opposite the front side 501. The solar cell 500 can include a silicon substrate 502. In an embodiment, the silicon substrate 502 can be a N-type silicon substrate. In an embodiment, a portion 506 of the silicon substrate 502 can have a doping concentration 522 of approximately equal to or less than $2 \times 10^{18} \text{ cm}^{-3}$.

[0052] [0053] The solar cell 500 can have a dielectric region 510 formed over the silicon substrate 502. In an embodiment, the dielectric 510 can be a tunnel oxide. In an embodiment, the dielectric region 510 can be silicon dioxide. In an embodiment, the solar cell 500 can have first and second emitter regions 512, 514. In an example, the first and second emitter regions 512, 514 can be P-type and/or N-type doped polysilicon regions, respectively. In one embodiment, the second emitter region 514 can be at least partially formed over the first emitter region 512, as shown. In an embodiment, a second dielectric region 513 can be formed over the first emitter region 512, e.g. to insulate the first emitter region 512 from the second emitter region 514. In some embodiments, the second dielectric region 513 can also be silicon dioxide. In an embodiment, an opening 515 can isolate the second emitter region 514 from the first metal contact 542.

[0053] [0054] In some embodiments, the dielectric region 510 and second silicon region 514 can be formed over the back side 501 of the solar cell 500.

[0054] [0055] In an example, impurities and/or contaminants 520, e.g. metal impurities and/or contaminants, can be located in the second emitter region 512 as shown. In an example, the metal impurities 520 can be iron, nickel and/or chromium among others. In one embodiment, the silicon substrate 502 can have some impurities 521 remaining after the heating process.

[0055] [0056] In an embodiment, the solar cell 500 can have first and second metal contacts 542, 544 formed on the first and second emitter regions 512, 514, respectively. In one embodiment, the solar cell 500 can have a textured surface 504 on the front side 501 and/or a textured surface 550 on the back side 503 as shown. In an example, the textured surfaces 504, 550 can be surfaces which can provide additional light absorption. In an embodiment, the portion 506 of the silicon substrate 502 can be above a textured surface 504 as shown. In some embodiments, an anti-reflective region 518 can be formed over the textured surface 504 of the solar cell 500.

Example Process	Temp	Surface Dopant Conc.	Gettering Location	Surface Passivation	Lifetime	Efficiency
A	≤ 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	non-poly	2 fA/cm^2	$\sim 3 \text{ msec}$	Baseline
B	≤ 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	non-poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline
C	> 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	poly	2 fA/cm^2	$\sim 10 \text{ msec}$	$+0.5\%$ abs.
D	> 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline

Table 1. Example Processes for Solar Cell Fabrication

[0056] [0057] Turning now to ~~Table 1~~ Figure 11, a table is shown listing Temperature and Surface Dopant Concentration and output results, such as Gettering Location, Surface Passivation, Lifetime and Efficiency, for example processes of fabricating solar cells.

[0057] [0058] The method of Figures 1-4 is exemplified in Example Process C of ~~Table 1~~ Figure 11, where a surface, or a portion near the surface, of a silicon substrate was doped at approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$

and the solar cell of Example Process C heated to a temperature above 900 degrees Celsius. The results from Example Process C are gettering in a polysilicon region of the silicon substrate, improved surface passivation at approximately 5 fA/cm², improved lifetime, e.g. typical of approximately 10 µsec, and a > 0.5 % efficiency increase as compared to other solar cells, e.g. referenced as the baseline efficiency.

[0058] [0059] In contrast, referring to Example Process A, a surface, or a portion near the surface, of the silicon substrate was doped at approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process A heated to a temperature below 900 degrees Celsius resulting in gettering in a non-polysilicon region of the solar cell, good surface passivation at approximately 2 fA/cm², poor lifetime, e.g. typical of approximately 3 µsec and no considerable, e.g., < 0.5%, efficiency increase from the baseline.

[0059] [0060] In another example, referring to Example Process B, a surface of the silicon substrate was doped at approximately $4 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process B heated to a temperature below 900 degrees Celsius resulting in gettering in a non-polysilicon region of the solar cell, poor surface passivation at approximately 5 fA/cm², good lifetime, e.g. typical of approximately 10 µsec and no considerable, e.g. < 0.5%, efficiency increase from the baseline.

[0060] [0061] In yet another example comparison, in Example Process D a surface of the silicon substrate was doped at approximately $4 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process D heated to a temperature above 900 degrees Celsius also resulted gettering in a polysilicon region of the silicon substrate, but poor surface passivation at approximately 5 fA/cm², good lifetime, e.g. typical of approximately 10 µsec and no considerable, e.g. < 0.5%, efficiency increase from the baseline.

[0061] [0062] In all Examples Processes A, B and D either the lifetime or surface passivation only was improved, and the Example Process C resulted in improved surface passivation, lifetime and efficiency.

[0062] [0063] With reference to Figures 8-10, example surface passivation, 1/lifetime and efficiency measurements, respectively, for solar cells fabricated using the methods of the Example Processes A and C of ~~Table 4~~ Figure 11 is shown. The results from Figures 8-10 show that the surface passivation, lifetime and efficiency of solar cells fabricated using the method of Figures 1-4, e.g., Example Process C, have improved surface passivation, lifetime and higher efficiency measurements as compared to the solar cells of Example process A.

[0063] [0064] Figure 8 illustrates a graph of surface passivation measurements from solar cells fabricated using the Example Process A and C from ~~Table 4~~ Figure 11. As shown, the Example Process C has lower passivation results as compared to Example Process A. Lower surface passivation is preferred for high efficiency solar cells. Thus, the Example Process C has improved surface passivation results as compared to Example Process A.

[0064] [0065] With reference to Figure 9, there is shown a graph of 1/lifetime measurements from solar cells fabricated using the Example Process A and C from ~~Table 4~~ Figure 11. As shown, the Example Process C has higher lifetime, lower 1/lifetime results, as compared to Example Process A. Higher lifetime is preferred for high efficiency solar cells. Thus, the Example Process C has improved lifetime results as compared to Example Process A.

[0065] [0066] Figure 10 illustrates a graph of efficiency measurements from solar cells fabricated using the Example Process A and C from ~~Table 4~~ Figure 11. As shown, the Example Process C has higher efficiency results as compared to Example Process A. Higher solar cell efficiency conversion is preferred to maximize the electricity conversion from collected light. Thus, the Example Process C has improved efficiency results over Example Process A.

[0066] [0067] The results of Figures 8-10 demonstrate that a solar cell fabrication technique of Figures 1-4 results in overall improvement for surface

passivation, lifetime and efficiency from other techniques, e.g. Example Processes A, B and D.

~~[0067]~~ **[0068]** Although specific embodiments have been described above, these embodiments are not intended to limit the scope of the present disclosure, even where only a single embodiment is described with respect to a particular feature. Examples of features provided in the disclosure are intended to be illustrative rather than restrictive unless stated otherwise. The above description is intended to cover such alternatives, modifications, and equivalents as would be apparent to a person skilled in the art having the benefit of this disclosure.

~~[0068]~~ **[0069]** The scope of the present disclosure includes any feature or combination of features disclosed herein (either explicitly or implicitly), or any generalization thereof, whether or not it mitigates any or all of the problems addressed herein. Accordingly, new claims may be formulated during prosecution of this application (or an application claiming priority thereto) to any such combination of features. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the appended claims.

CLAIMS

What is claimed is:

1. A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
 - a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the back side of the solar cell;
 - a first dielectric region formed over the silicon substrate, wherein the first dielectric region is formed over the front side of solar;
 - a first emitter region having metal impurities formed over the first dielectric region; and
 - a first metal contact formed over the first emitter region.
2. The solar cell of claim 1, wherein the portion of the silicon substrate comprises N-type dopants.
3. The solar cell of claim 1, wherein the portion of the silicon substrate comprises phosphorus.
4. The solar cell of claim 1, wherein the portion of the silicon substrate comprises P-type dopants.
5. The solar cell of claim 1, wherein the portion of the silicon substrate comprises boron.
6. The solar cell of claim 1, wherein the first emitter region comprises polysilicon.

7. The solar cell of claim 1, further comprising:
 - a second emitter region having metal impurities formed over the silicon substrate, wherein the second emitter region is formed over the back side of solar; and
 - a second metal contact formed over the second emitter region.
8. The solar cell of claim 1, further comprising:
 - a second dielectric region formed over the silicon substrate, wherein the second dielectric region is formed over the back side of solar;
 - a second emitter region having metal impurities formed over the second dielectric region; and
 - a second metal contact formed over the second emitter region.
9. The solar cell of claim 8, wherein the second emitter region comprises polysilicon.
10. A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
 - a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the front side of the solar cell;
 - a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;
 - a first emitter region having metal impurities formed over the dielectric region; and
 - a first metal contact formed over the first emitter region.

11. The solar cell of claim 10, wherein the portion of the silicon substrate comprises N-type dopants.

12. The solar cell of claim 10, wherein the portion of the silicon substrate comprises phosphorus.

13. The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants.

14. The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron.

15. The solar cell of claim 10, wherein the first emitter region comprises polysilicon.

16. The solar cell of claim 10, further comprising:
a second emitter region having metal impurities formed over the dielectric region; and
a second metal contact formed over the second emitter region.

17. The solar cell of claim 16, wherein the second emitter region is separate from the first emitter region.

18. The solar cell of claim 16, wherein a trench region separates the first emitter region from the second emitter region.

19. The solar cell of claim 16, wherein the second emitter region comprises polysilicon.

20. The solar cell of claim 16, wherein the first emitter region comprises a P-type doped polysilicon region and the second emitter region comprises a N-type doped polysilicon region.

ABSTRACT OF THE DISCLOSURE

A method of fabricating a solar cell can include forming a dielectric region on a silicon substrate. The method can also include forming an emitter region over the dielectric region and forming a dopant region on a surface of the silicon substrate. In an embodiment, the method can include heating the silicon substrate at a temperature above 900 degrees Celsius to getter impurities to the emitter region and drive dopants from the dopant region to a portion of the silicon substrate.

CLEAN VERSION OF SUBSTITUTE SPECIFICATION

SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR
EFFICIENCY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. Patent Application No. 16/228,165, filed on December 20, 2018, which is a divisional of U.S. Patent Application No. 15/876,927, filed on January 22, 2018, now U.S. Patent No. 10,170,642, issued on January 1, 2019, which is a continuation of U.S. Patent Application No. 15/213,273, filed on July 18, 2016, now U.S. Patent No. 9,899,542, issued on February 20, 2018, which is a continuation of U.S. Patent Application No. 14/579,935, filed on December 22, 2014, now U.S. Patent No. 9,520,507, issued on December 13, 2016, the entire contents of which are hereby incorporated by reference herein.

BACKGROUND

[0002] Photovoltaic (PV) cells, commonly known as solar cells, are devices for conversion of solar radiation into electrical energy. Generally, solar radiation impinging on the surface of, and entering into, the substrate of a solar cell creates electron and hole pairs in the bulk of the substrate. The electron and hole pairs migrate to p-doped and n-doped regions in the substrate, thereby creating a voltage differential between the doped regions. The doped regions are connected to the conductive regions on the solar cell to direct an electrical current from the cell to an external circuit. When PV cells are combined in an array such as a PV module, the electrical energy collect from all of the PV cells can be combined in series and parallel arrangements to provide power with a certain voltage and current.

[0003] Efficiency is an important characteristic of a solar cell as it is directly related to the solar cell's capability to generate power. Accordingly, techniques for improving the fabrication process, reducing the cost of

manufacturing and increasing the efficiency of solar cells are generally desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0005] Figure 1 illustrates a flow chart representation of an example method for fabricating of a solar cell, according to some embodiments.

[0006] Figures 2-4 illustrate cross-sectional views of example solar cells during the fabrication process of Figure 1, according to some embodiments.

[0007] Figure 5 illustrates a cross-sectional view of an example solar cell, according to some embodiments.

[0008] Figure 6 illustrates a cross-sectional view of another example solar cell, according to some embodiments.

[0009] Figure 7 illustrates a cross-sectional view of still another example solar cell, according to some embodiments.

[0010] Figure 8 illustrates a graph of example surface passivation measurements, according to some embodiments.

[0011] Figure 9 illustrates a graph of example 1/lifetime measurements, according to some embodiments.

[0012] Figure 10 illustrates a graph of example efficiency measurements, according to some embodiments.

[0013] Figure 11 illustrates example processes for solar cell fabrication.

DETAILED DESCRIPTION

[0014] The following detailed description is merely illustrative in nature and is not intended to limit the embodiments of the subject matter of the application or uses of such embodiments. As used herein, the word “exemplary” means “serving as an example, instance, or illustration.” Any implementation described herein as exemplary is not necessarily to be construed as preferred or advantageous over other implementations. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

[0015] This specification includes references to “one embodiment” or “an embodiment.” The appearances of the phrases “in one embodiment” or “in an embodiment” do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

[0016] Terminology. The following paragraphs provide definitions and/or context for terms found in this disclosure (including the appended claims):

[0017] “Comprising.” This term is open-ended. As used in the appended claims, this term does not foreclose additional structure or steps.

[0018] “Configured To.” Various units or components may be described or claimed as “configured to” perform a task or tasks. In such contexts, “configured to” is used to connote structure by indicating that the units/components include structure that performs those task or tasks during operation. As such, the unit/component can be said to be configured to perform the task even when the specified unit/component is not currently operational (e.g., is not on/active). Reciting that a unit/circuit/component is “configured to” perform one or more tasks is expressly intended not to invoke 35 U.S.C. §112, sixth paragraph, for that unit/component.

[0019] “First,” “Second,” etc. As used herein, these terms are used as labels for nouns that they precede, and do not imply any type of ordering (e.g.,

spatial, temporal, logical, etc.). For example, reference to a “first” emitter region does not necessarily imply that this emitter region is the first emitter region in a sequence; instead the term “first” is used to differentiate this emitter region from another emitter region (e.g., a “second” emitter region). In an embodiment, an emitter region can be a doped region of a solar cell for collecting positive and negative charge carriers. In an example, the emitter region can be a doped polysilicon region. In one example, the emitter region can be a P-type doped polysilicon region or an N-type doped polysilicon region.

[0020] “Based On.” As used herein, this term is used to describe one or more factors that affect a determination. This term does not foreclose additional factors that may affect a determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase “determine A based on B.” While B may be a factor that affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.

[0021] “Coupled” – The following description refers to elements or nodes or features being “coupled” together. As used herein, unless expressly stated otherwise, “coupled” means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically.

[0022] In addition, certain terminology may also be used in the following description for the purpose of reference only, and thus are not intended to be limiting. For example, terms such as “upper”, “lower”, “above”, and “below” refer to directions in the drawings to which reference is made. Terms such as “front”, “back”, “rear”, “side”, “outboard”, and “inboard” describe the orientation and/or location of portions of the component within a consistent but arbitrary frame of reference which is made clear by reference to the text and the associated drawings describing the component under discussion. Such

terminology may include the words specifically mentioned above, derivatives thereof, and words of similar import.

[0023] In the following description, numerous specific details are set forth, such as specific operations, in order to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to one skilled in the art that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known techniques are not described in detail in order to not unnecessarily obscure embodiments of the present disclosure.

[0024] This specification first describes solar cell fabrication techniques to improve solar cell lifetime, passivation and/or efficiency followed by a description of example solar cells fabricated according to the disclosed techniques. Various embodiments are provided throughout followed by example results from the disclosed techniques.

[0025] Turning now to Figure 1, a method for fabricating a solar cell is shown, according to some embodiments. In various embodiments, the method of Figure 1 can include additional (or fewer) blocks than illustrated. For example, in some embodiments, the silicon region formed at block 102 can be heated to form a polysilicon region after step 102 but before to the heating step of block 106.

[0026] At 100, a dielectric can be formed on a silicon substrate of a solar cell. In some embodiments, the silicon substrate can be cleaned, polished, planarized, and/or thinned or otherwise processed prior to the formation of the dielectric region. In an embodiment, the silicon substrate can be single-crystalline or a multicrystalline silicon substrate. In an embodiment, the silicon substrate can be a N-type silicon substrate. In an embodiment, the dielectric can be a tunnel oxide. In one embodiment, the dielectric can be silicon dioxide. In an embodiment, the dielectric region can be grown and/or formed through a thermal process.

[0027] At 102, an emitter region can be formed over the dielectric region. In an embodiment, the emitter region can be an amorphous silicon region. In

some embodiments, the amorphous silicon region can be grown over the dielectric region. In an embodiment, the emitter region can be polysilicon. In an embodiment, the emitter region can be grown and/or formed through a thermal process. In an example, an amorphous silicon region can be formed over the dielectric region and heated to form a polysilicon region.

[0028] An emitter dopant region can be deposited over the emitter region through a deposition process. The emitter dopant region can comprise a dopant, such as a positive-type doping material such as boron or a negative-type doping material such as phosphorous.

[0029] Although the dielectric region and/or the emitter region are described as being grown by a thermal process or deposited through conventional deposition process, respectively, as with any other formation, deposition, or growth process step described or recited here, each layer or substance can be formed using any appropriate process. For example, a chemical vapor deposition (CVD) process, low-pressure CVD (LPCVD), atmospheric pressure CVD (APCVD), plasma-enhanced CVD (PECVD), thermal growth, sputtering, as well as any other desired technique can be used where formation is described. Thus, and similarly, the emitter dopant region can be formed on the substrate by a deposition technique, implant process, sputter, or print process, such as inkjet printing or screen printing.

[0030] In an embodiment, a heating process can be performed to drive dopants from the emitter dopant region to the emitter region. In one example, the heating process can drive dopants from the emitter dopant region to a polysilicon region to form a doped polysilicon region. In an embodiment, the doped polysilicon region can be doped with a P-type dopant such as boron or an N-type dopant such as phosphorus. In one example, the doped polysilicon regions can be formed in alternating P-type and N-type regions. In some embodiments, the heating to drive dopants from the emitter dopant region to the emitter region, can be performed at a temperature below 900 degrees Celsius.

[0031] At 104, a dopant region can be formed over a surface of the silicon substrate. In an embodiment, the dopant region can be grown and/or formed through a thermal process. In one example, the dopant region can be formed over a surface, e.g., on the front side of a solar cell, and subsequently a heating process can be performed to drive dopants into a portion of the silicon substrate. In an embodiment, the portion of the silicon substrate can have a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ after the heating process as discussed in block 106.

[0032] In one embodiment, the dopant region can be an N-type dopant, e.g., phosphorus. In an embodiment, the surface of the silicon substrate over which the dopant region is formed can be a front side, back side, or both on the front and back sides of the solar cell. Figure 2 shows an example solar cell having the dielectric region, emitter region and dopant region described above.

[0033] Although the dopant region is described as being grown by a thermal process or deposited through conventional deposition process, respectively, as with any other formation, deposition, or growth process step described or recited here, each layer or substance can be formed using any appropriate process. For example, a chemical vapor deposition (CVD) process, low-pressure CVD (LPCVD), atmospheric pressure CVD (APCVD), plasma-enhanced CVD (PECVD), thermal growth, sputtering, as well as any other desired technique can be used where formation is described.

[0034] Figure 2 illustrates an example solar cell after forming the dielectric region, emitter region, and dopant region, according to some embodiments. In an embodiment, a dielectric region 210 can be formed over a silicon substrate 202 of the solar cell 200. In an embodiment, the dielectric region 210 can be a tunnel oxide. In one example, the dielectric region 210 can be silicon dioxide. In an embodiment, an emitter region 212 can be formed on the dielectric region 210. In an embodiment and as noted above, the emitter region 212 can be amorphous silicon or polysilicon. In an embodiment, the emitter region 212 can be a doped polysilicon. In an example, the doped polysilicon can be N-type doped or P-type doped polysilicon.

[0035] In an embodiment, a dopant region 216 can be formed on a surface 204 of silicon substrate 202. In an embodiment, the dopant region 216 can be formed to dope the surface 204 (e.g., at block 106 below) to repel charge carriers and prevent and/or reduce recombination at the surface 204 of the solar cell 200. In an example, the surface 204, can be on a front side and/or a back side of the solar cell. In one example, the dopant region 216 can be a N-type dopant region, such as phosphorus. In an embodiment, the dopant region 216 can have positive or negative type dopants 222.

[0036] In an embodiment, the silicon substrate 202 can have contaminants and/or impurities 220, for example metal contaminants and/or metal impurities, such as iron, nickel and/or chromium among others. Metal impurities can be detrimental to the electrical conduction of the solar cell as these impurities can be sources of recombination, resulting in poor lifetime, surface passivation and/or lower solar cell efficiency. In an embodiment, the impurities 220 can be located at or near a surface 204 of the silicon substrate 202. In an embodiment, the impurities 220 can be located within the silicon substrate 202 as shown. As referred throughout, contaminants and/or impurities can be used interchangeably.

[0037] The emitter regions 212, e.g., polysilicon regions, can be a good sink and/or trap for the metal impurities 220 discussed above. A gettering process can be used to trap the metal impurities 220 in the emitter regions 212, reducing recombination within the silicon substrate 202 and improving overall solar cell lifetime. Oxides and/or tunnel oxides, such as the dielectric region 210 of Figure 2, can be barriers to gettering of the metal impurities 220 to emitter regions 212. In one example, heating at temperature at 900 degrees Celsius or below can be insufficient to diffuse metal impurities through a tunnel oxide and into a polysilicon region. Thus, in an embodiment, heating at temperatures above 900 degrees Celsius can include gettering metal impurities 220 through the dielectric region 210, e.g., tunnel oxide, to into the emitter region 212, e.g., polysilicon regions, as discussed in detail at 106 of Figure 1 below.

[0038] At 106, the solar cell can be heated at a temperature above 900 degrees Celsius. In an embodiment, the heating can drive dopants from the dopant region to a portion of the silicon substrate. In one embodiment, the heating can include performing an annealing process on the silicon substrate. In an example, the heating can drive dopants to the portion of the silicon substrate located above the surface, as shown in Figure 3. In some embodiments, the surface can be on the front side, back side or both on the front and back side of the solar cell. In an embodiment, the heating can include gettering contaminants, e.g. metal impurities and/or metal contaminants, from the substrate to the emitter region. In an example, the metal impurities and/or metal contaminants can be iron, nickel and/or chromium among others.

[0039] In one example, the heating can include placing the solar cell in thermal tool, e.g., a thermal furnace or oven among others, and raising the temperature in the thermal tool to 975 degrees Celsius or above.

[0040] In an embodiment, the heating can be the last heating step in the solar cell fabrication process. In one embodiment, the heating can be the only heating step in the fabrication process. In some embodiments, at least one other heating step can be performed before the heating process of block 106. In one example, the other heating process, aside from the heating process of block 106, can include heating the solar cell to temperature below 900 degrees Celsius. In an example, the heating process below 900 degrees Celsius can be performed before the heating process at 106. In an embodiment, the heating performed at 106 can be performed at the highest temperature among other heating steps performed in the solar cell fabrication process. Figure 3 illustrates the heating process described above.

[0041] Figure 3 illustrates heating the solar cell of Figure 2, according to some embodiments. In an embodiment, the heating 230 can include heating the solar cell 200 above 900 degrees Celsius. In an example, the heating can include placing the solar cell 200 into a thermal tool, e.g., thermal furnace or oven among others, and raising the temperature within the thermal tool to 975 degrees Celsius or higher. In an embodiment, the heating 230 can drive 234

the dopants 222 from the dopant region 216 to a portion 206 of the silicon substrate 202. In an example, the dopant concentration of the portion 206 of the silicon substrate 202 can be approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ after the heating. In an embodiment, the portion 206 of the silicon substrate 202 can be above, as shown, the surface 204 of the silicon substrate 202. In an embodiment, the heating 230 can getter 232 contaminants 220 from, or nearby, the surface 204 of the silicon substrate 202 and/or from within the silicon substrate 202 to the emitter region 212. In an embodiment, the heating 230 can getter 232 the containments 220 through the dielectric region 210 to the emitter region 212.

[0042] At 108, a metal contact can be formed over the silicon substrate. In an embodiment, the metal contact can be formed on the emitter region. In some embodiments, the metal contact can be formed by a metallization process. In one example, the metallization process can include plating and/or electroplating the metal contact to the emitter region. In some embodiments, the metal contact can be formed by printing and/or foil-based metallization techniques. Figure 4 illustrates an example silicon substrate after to forming the metal contact. Also Figure 4 illustrates a single metal contact, for example, which can be on a front side or back side of the solar cell. In an embodiment, multiple metal contacts can exist. In an example, positive and negative metal contacts can be formed in an interdigitated pattern.

[0043] With reference to Figure 4, the solar cell of Figure 3 is shown after forming a metal contact, according to some embodiments. In an embodiment, the metal contact 242 can be formed on the emitter region 212, e.g. over the silicon substrate 202. In an example, the metal contact 242 can be formed by an electroplating process, printing process or a foil-based metallization process among others. In an embodiment, the metal contact 242 can be a positive or negative metal contact. As shown in Figure 4 a single metal contact is illustrated for example, which can be on a front side or back side of the solar cell. In an example, multiple metal contacts, e.g. some positive and others

negative, can exist. In one embodiment, the silicon substrate 202 can have some impurities 221 remaining after the heating 230 of Figure 3.

[0044] Figure 5 illustrates a cross-section of a portion of a solar cell formed from the method of Figures 1-4, according to some embodiments. The solar cell 300 can have a front side 301 which faces the sun during normal operation and a back side 303 opposite the front side 301. The solar cell 300 can include a silicon substrate 302. In an embodiment, the silicon substrate 302 can be an N-type silicon substrate. In an embodiment, a portion 306 of the silicon substrate 302 can have a doping concentration 322 of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$.

[0045] The solar cell 300 can have a dielectric region 310 formed over the silicon substrate 302. In an embodiment, the dielectric 310 can be a tunnel oxide. In some embodiments, the dielectric region 310 can be silicon dioxide. In an embodiment, the solar cell 300 can have first and second emitter regions 312, 314. In an example, the first and second emitter regions 312, 314 can be P-type and N-type doped polysilicon regions, respectively. In an example, impurities and/or contaminants 320, e.g. metal impurities 320 and/or metal contaminants, can be located in the first and second emitter regions 312, 314 as shown. In one embodiment, the silicon substrate 302 can have some impurities 321 remaining after the gettering process.

[0046] In an embodiment, the solar cell 300 can have first and second metal contacts 342, 344 formed on the first and second emitter regions 312, 314, respectively. In some embodiments, a trench region 305 can be formed, which can separate the first and second emitter regions 312, 314. In an embodiment, the solar cell 300 can have a textured surface 304 on the front side 301. In an example, the textured surface 304 can be a surface which can provide additional light absorption. In an embodiment, the portion 306 of the silicon substrate 302 can be formed above a textured surface 304 as shown. In some embodiments, the trench region 305 can also be textured, similar to the textured surface 304, for additional light absorption from the back side 303 of the solar cell 300. In some embodiments, an anti-reflective region (ARC) 318

can be formed over the textured surface 304 of the solar cell 300. In some embodiments, the anti-reflective region 318 can be silicon nitride.

[0047] In an embodiment, the solar cell 300 can be a back contact solar cell, for example, as shown in Figures 5 and 7.

[0048] With reference to Figure 6, a front contact solar cell formed from the method of Figures 1-4 is shown, according to some embodiments. The solar cell 400 can have a front side 401 which faces the sun during normal operation and a back side 403 opposite the front side 401. The solar cell 400 can include a silicon substrate 402. In an embodiment, the silicon substrate 402 can be a N-type silicon substrate. In an embodiment, a portion 406 of the silicon substrate 402 can have a doping concentration 422 of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$.

[0049] The solar cell 400 can have a dielectric 410 formed over the silicon substrate 402. In an embodiment, the dielectric 410 can be a tunnel oxide. In some embodiments, the dielectric 410 can be silicon dioxide. In an embodiment, the solar cell 400 can have first and second emitter regions 412, 414. In some embodiments, the first emitter region 412 can be formed on the back side 403 of the solar cell 400 and the second emitter region 414 can be formed on the front side 401 of the solar cell 400. In an example, the first and second emitter regions 412, 414 can be P-type and/or N-type doped polysilicon regions.

[0050] In an embodiment, the solar cell 400 can have first and second metal contacts 442, 444 formed on the first and second emitter regions 412, 414, respectively. In an embodiment, the solar cell 400 can have a textured surface 404 on the front side 401. In an example, the textured surface 404 can be a surface which can provide additional light absorption. In an embodiment, the portion 406 of the silicon substrate 402 can be above a textured surface 404 as shown. In some embodiments, an anti-reflective region (ARC) 418 can be formed over the textured surface 404 of the solar cell 400. In some embodiments, the anti-reflective region 418 can be silicon nitride.

[0051] In an example, impurities and/or contaminants 420, e.g. metal impurities and/or contaminants, can be located in the first and second emitter regions 412, 414. In one embodiment, the silicon substrate 402 can have some impurities 421 remaining after the gettering process.

[0052] Figure 7 illustrates still another solar cell formed from the method of Figures 1-4, according to some embodiments. The solar cell 500 can have a front side 501 which faces the sun during normal operation and a back side 503 opposite the front side 501. The solar cell 500 can include a silicon substrate 502. In an embodiment, the silicon substrate 502 can be a N-type silicon substrate. In an embodiment, a portion 506 of the silicon substrate 502 can have a doping concentration 522 of approximately equal to or less than $2 \times 10^{18} \text{ cm}^{-3}$.

[0053] The solar cell 500 can have a dielectric region 510 formed over the silicon substrate 502. In an embodiment, the dielectric 510 can be a tunnel oxide. In an embodiment, the dielectric region 510 can be silicon dioxide. In an embodiment, the solar cell 500 can have first and second emitter regions 512, 514. In an example, the first and second emitter regions 512, 514 can be P-type and/or N-type doped polysilicon regions, respectively. In one embodiment, the second emitter region 514 can be at least partially formed over the first emitter region 512, as shown. In an embodiment, a second dielectric region 513 can be formed over the first emitter region 512, e.g. to insulate the first emitter region 512 from the second emitter region 514. In some embodiments, the second dielectric region 513 can also be silicon dioxide. In an embodiment, an opening 515 can isolate the second emitter region 514 from the first metal contact 542.

[0054] In some embodiments, the dielectric region 510 and second silicon region 514 can be formed over the back side 501 of the solar cell 500.

[0055] In an example, impurities and/or contaminants 520, e.g. metal impurities and/or contaminants, can be located in the second emitter region 512 as shown. In an example, the metal impurities 520 can be iron, nickel

and/or chromium among others. In one embodiment, the silicon substrate 502 can have some impurities 521 remaining after the heating process.

[0056] In an embodiment, the solar cell 500 can have first and second metal contacts 542, 544 formed on the first and second emitter regions 512, 514, respectively. In one embodiment, the solar cell 500 can have a textured surface 504 on the front side 501 and/or a textured surface 550 on the back side 503 as shown. In an example, the textured surfaces 504, 550 can be surfaces which can provide additional light absorption. In an embodiment, the portion 506 of the silicon substrate 502 can be above a textured surface 504 as shown. In some embodiments, an anti-reflective region 518 can be formed over the textured surface 504 of the solar cell 500.

[0057] Turning now to Figure 11, a table is shown listing Temperature and Surface Dopant Concentration and output results, such as Gettering Location, Surface Passivation, Lifetime and Efficiency, for example processes of fabricating solar cells.

[0058] The method of Figures 1-4 is exemplified in Example Process C of Figure 11, where a surface, or a portion near the surface, of a silicon substrate was doped at approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process C heated to a temperature above 900 degrees Celsius. The results from Example Process C are gettering in a polysilicon region of the silicon substrate, improved surface passivation at approximately 5 fA/cm^2 , improved lifetime, e.g. typical of approximately $10 \text{ } \mu\text{sec}$, and a $> 0.5 \%$ efficiency increase as compared to other solar cells, e.g. referenced as the baseline efficiency.

[0059] In contrast, referring to Example Process A, a surface, or a portion near the surface, of the silicon substrate was doped at approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process A heated to a temperature below 900 degrees Celsius resulting in gettering in a non-polysilicon region of the solar cell, good surface passivation at approximately 2 fA/cm^2 , poor lifetime, e.g. typical of approximately $3 \text{ } \mu\text{sec}$ and no considerable, e.g., $< 0.5\%$, efficiency increase from the baseline.

[0060] In another example, referring to Example Process B, a surface of the silicon substrate was doped at approximately $4 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process B heated to a temperature below 900 degrees Celsius resulting in gettering in a non-polysilicon region of the solar cell, poor surface passivation at approximately 5 fA/cm^2 , good lifetime, e.g. typical of approximately 10 μsec and no considerable, e.g. $< 0.5\%$, efficiency increase from the baseline.

[0061] In yet another example comparison, in Example Process D a surface of the silicon substrate was doped at approximately $4 \times 10^{18} \text{ cm}^{-3}$ and the solar cell of Example Process D heated to a temperature above 900 degrees Celsius also resulted gettering in a polysilicon region of the silicon substrate, but poor surface passivation at approximately 5 fA/cm^2 , good lifetime, e.g. typical of approximately 10 μsec and no considerable, e.g. $< 0.5\%$, efficiency increase from the baseline.

[0062] In all Examples Processes A, B and D either the lifetime or surface passivation only was improved, and the Example Process C resulted in improved surface passivation, lifetime and efficiency.

[0063] With reference to Figures 8-10, example surface passivation, 1/lifetime and efficiency measurements, respectively, for solar cells fabricated using the methods of the Example Processes A and C of Figure 11 is shown. The results from Figures 8-10 show that the surface passivation, lifetime and efficiency of solar cells fabricated using the method of Figures 1-4, e.g., Example Process C, have improved surface passivation, lifetime and higher efficiency measurements as compared to the solar cells of Example process A.

[0064] Figure 8 illustrates a graph of surface passivation measurements from solar cells fabricated using the Example Process A and C from Figure 11. As shown, the Example Process C has lower passivation results as compared to Example Process A. Lower surface passivation is preferred for high efficiency solar cells. Thus, the Example Process C has improved surface passivation results as compared to Example Process A.

[0065] With reference to Figure 9, there is shown a graph of 1/lifetime measurements from solar cells fabricated using the Example Process A and C from Figure 11. As shown, the Example Process C has higher lifetime, lower 1/lifetime results, as compared to Example Process A. Higher lifetime is preferred for high efficiency solar cells. Thus, the Example Process C has improved lifetime results as compared to Example Process A.

[0066] Figure 10 illustrates a graph of efficiency measurements from solar cells fabricated using the Example Process A and C from Figure 11. As shown, the Example Process C has higher efficiency results as compared to Example Process A. Higher solar cell efficiency conversion is preferred to maximize the electricity conversion from collected light. Thus, the Example Process C has improved efficiency results over Example Process A.

[0067] The results of Figures 8-10 demonstrate that a solar cell fabrication technique of Figures 1-4 results in overall improvement for surface passivation, lifetime and efficiency from other techniques, e.g. Example Processes A, B and D.

[0068] Although specific embodiments have been described above, these embodiments are not intended to limit the scope of the present disclosure, even where only a single embodiment is described with respect to a particular feature. Examples of features provided in the disclosure are intended to be illustrative rather than restrictive unless stated otherwise. The above description is intended to cover such alternatives, modifications, and equivalents as would be apparent to a person skilled in the art having the benefit of this disclosure.

[0069] The scope of the present disclosure includes any feature or combination of features disclosed herein (either explicitly or implicitly), or any generalization thereof, whether or not it mitigates any or all of the problems addressed herein. Accordingly, new claims may be formulated during prosecution of this application (or an application claiming priority thereto) to any such combination of features. In particular, with reference to the appended claims, features from dependent claims may be combined with

those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the appended claims.

CLAIMS

What is claimed is:

1. A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
 - a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the back side of the solar cell;
 - a first dielectric region formed over the silicon substrate, wherein the first dielectric region is formed over the front side of solar;
 - a first emitter region having metal impurities formed over the first dielectric region; and
 - a first metal contact formed over the first emitter region.
2. The solar cell of claim 1, wherein the portion of the silicon substrate comprises N-type dopants.
3. The solar cell of claim 1, wherein the portion of the silicon substrate comprises phosphorus.
4. The solar cell of claim 1, wherein the portion of the silicon substrate comprises P-type dopants.
5. The solar cell of claim 1, wherein the portion of the silicon substrate comprises boron.
6. The solar cell of claim 1, wherein the first emitter region comprises polysilicon.

7. The solar cell of claim 1, further comprising:
 - a second emitter region having metal impurities formed over the silicon substrate, wherein the second emitter region is formed over the back side of solar; and
 - a second metal contact formed over the second emitter region.
8. The solar cell of claim 1, further comprising:
 - a second dielectric region formed over the silicon substrate, wherein the second dielectric region is formed over the back side of solar;
 - a second emitter region having metal impurities formed over the second dielectric region; and
 - a second metal contact formed over the second emitter region.
9. The solar cell of claim 8, wherein the second emitter region comprises polysilicon.
10. A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
 - a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the front side of the solar cell;
 - a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;
 - a first emitter region having metal impurities formed over the dielectric region; and
 - a first metal contact formed over the first emitter region.

11. The solar cell of claim 10, wherein the portion of the silicon substrate comprises N-type dopants.

12. The solar cell of claim 10, wherein the portion of the silicon substrate comprises phosphorus.

13. The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants.

14. The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron.

15. The solar cell of claim 10, wherein the first emitter region comprises polysilicon.

16. The solar cell of claim 10, further comprising:
a second emitter region having metal impurities formed over the dielectric region; and
a second metal contact formed over the second emitter region.

17. The solar cell of claim 16, wherein the second emitter region is separate from the first emitter region.

18. The solar cell of claim 16, wherein a trench region separates the first emitter region from the second emitter region.

19. The solar cell of claim 16, wherein the second emitter region comprises polysilicon.

20. The solar cell of claim 16, wherein the first emitter region comprises a P-type doped polysilicon region and the second emitter region comprises a N-type doped polysilicon region.

ABSTRACT OF THE DISCLOSURE

A method of fabricating a solar cell can include forming a dielectric region on a silicon substrate. The method can also include forming an emitter region over the dielectric region and forming a dopant region on a surface of the silicon substrate. In an embodiment, the method can include heating the silicon substrate at a temperature above 900 degrees Celsius to getter impurities to the emitter region and drive dopants from the dopant region to a portion of the silicon substrate.



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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
16/877,255	05/18/2020	1757	1980	131815-255190_P167C2DC	20	2

CONFIRMATION NO. 2637

UPDATED FILING RECEIPT



0000000120971797

149776

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1211 SW FIFTH AVENUE
PORTLAND, OR 97204

Date Mailed: 11/03/2020

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.

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Applicant(s)

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Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 16/228,165 12/20/2018 PAT 10658525
which is a DIV of 15/876,927 01/22/2018 PAT 10170642
which is a CON of 15/213,273 07/18/2016 PAT 9899542
which is a CON of 14/579,935 12/22/2014 PAT 9520507

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

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If Required, Foreign Filing License Granted: 05/26/2020

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/877,255**

Projected Publication Date: 02/11/2021

Non-Publication Request: No

Early Publication Request: No
Title

SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY

Preliminary Class

136

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

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	Application Number	16/877,255
	Filing Date	May 18, 2020
	First Named Inventor	Smith, David D.
	Group Art Unit	2829
	Examiner Name	Unassigned
Sheet 1 of 1	Attorney Docket No: 131815-255190_P167C2DC	

US PATENT DOCUMENTS					
Examiner Initial *	Cite No ¹	USP Document Number	Publication or Issue Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 2014/360571	12-11-2014	Ji, et al.	

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OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
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		Official Communication from European Patent Application No. 15874267.6 (Attorney Docket No. S1117-EP) dated December 8, 2020, 15 pgs.	

EXAMINER

DATE CONSIDERED

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449)
 * 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. † Applicant's unique citation designation number (optional) ‡ Applicant is to place a check mark here if English language Translation is attached

Electronic Acknowledgement Receipt	
EFS ID:	41354920
Application Number:	16877255
International Application Number:	
Confirmation Number:	2637
Title of Invention:	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY
First Named Inventor/Applicant Name:	David D. Smith
Customer Number:	149776
Filer:	Justin K. Brask/Blanche Niksich
Filer Authorized By:	Justin K. Brask
Attorney Docket Number:	131815-255190_P167C2DC
Receipt Date:	10-DEC-2020
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Application Type:	Utility under 35 USC 111(a)

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File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		7923P167C2DC_IDS.pdf	168342	yes	2
			be1217e807dae90852deefb4993f903850203e40		

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application No.	16/877,255
Filing Date	May 18, 2020
First Inventor	Smith, David D.
Art Unit	2829
Examiner Name	Unassigned
Attorney Docket No.	131815-255190_P167C2DC
Conf. No.	2637

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In accordance with the duty of disclosure, enclosed is a copy of an Information Disclosure Statement (IDS) Citation Form PTO/SB/08 or PTO-1449, together with copies of the documents cited on that form, except for copies not required to be submitted (e.g., copies of U.S. patents and U.S. published patent applications need not be enclosed). It is respectfully requested that the cited references be considered and that the enclosed copy of PTO/SB/08 be initiated by the Examiner to indicate such consideration and a copy thereof returned to applicant(s).

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OR

☒ None

☐ The IDS Filing Fee in the amount of \$260.00 as set forth in 37 CFR 1.17(p) has been submitted herewith.

☒ It is requested that any requisite fees be debited from Deposit Account 50-0393.

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Signature	/Justin K. Brask/	Date (MM-DD-YYYY)	12-10-2020
Name/Print	Justin K. Brask	Registration Number	61,080

I hereby certify that this correspondence is being submitted electronically via EFS Web on the date shown below.

Gigi Hoover /Gigi Hoover/

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16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC

CONFIRMATION NO. 2637

PUBLICATION NOTICE



149776

Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

Title:SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY

Publication No.US-2021-0043782-A1

Publication Date:02/11/2021

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC	2637
149776 7590 06/28/2021 Schwabe Williamson & Wyatt/SunPower PACWEST CENTER, SUITE 1900 1211 SW FIFTH AVENUE PORTLAND, OR 97204			EXAMINER TRAN, LONG K	
			ART UNIT 2829	PAPER NUMBER
			NOTIFICATION DATE 06/28/2021	DELIVERY MODE 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):

IPDocketing@SCHWABE.com
ghoover@schwabe.com
mscardina@schwabe.com



UNITED STATES DEPARTMENT OF COMMERCE
U.S. Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450

APPLICATION NO./ CONTROL NO.	FILING DATE	FIRST NAMED INVENTOR/ PATENT IN REEXAMINATION	ATTORNEY DOCKET NO.
16/877,255	05/18/2020	Smith et al.	131815-255190_P16

Schwabe Williamson & Wyatt/SunPower PACWEST CENTER, SUITE 1900 1211 SW FIFTH AVENUE PORTLAND, OR 97204		EXAMINER	
		Long Tran	
		ART UNIT	PAPER
		2829	20210624

DATE MAILED: _____

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

Commissioner for Patents

Please see the attached decision pertaining to the petition to accept color drawings dated 27 October 2020.

/LAUREN R BELL/
Primary Examiner, Art Unit 2816

/DEAN A REICHARD/
TQAS, TC 2800



UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

<i>In re</i> Application of: David Smith	:	
Serial No.: 16877255	:	
Filed: May 18, 2020	:	
Docket: 131815-255190_P167C2DC	:	DECISION ON PETITION
Title: SOLAR CELLS WITH IMPROVED	:	UNDER 37 C.F.R. § 1.84(a)(2) TO
LIFETIME, PASSIVATION AND/OR	:	ACCEPT COLOR DRAWINGS
EFFICIENCY	:	

This decision is in response to the petition under 37 CFR 1.84(a)(2) for acceptance of color drawings, filed 27 October 2020.

The petition is **DISMISSED**.

Review of Facts

Applicant filed a petition requesting acceptance of color drawings on 27 October 2020.

Regulation and Practice

According to **37 CFR 1.84(a)(2)** in part states:

“The Office will accept color drawings in utility patent applications only after granting a petition filed under this paragraph explaining why the color drawings are necessary...Any such petition must include the following:

- (i) The fee set forth in 37 C.F.R. §1.17(h);
- (ii) One (1) set of the color drawings if submitted via the Office electronic filing system or three (3) sets of the color drawings if not submitted via the Office electronic filing system; and
- (iii) An amendment to the specification (unless the specification contains or has been previously amended to contain) the following language as the first paragraph of the brief description of the drawings:

“The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.”

MPEP 608.02(VIII) in part states:

"It is anticipated that such a petition will be granted only when the U.S. Patent and Trademark Office has determined that a color drawing or color photograph is the only practical medium by which to disclose in a printed utility patent the subject matter to be patented."

Analysis and Decision

In accordance with 37 CFR 1.84(a)(2), the petition is deficient for the following reasons: it does not appear that color drawings are present in the file wrapper. See 37 CFR 1.84(a)(2)(ii), reproduced above.

Accordingly, the petition is **DISMISSED**.

Any request for reconsideration of this decision must be submitted within TWO (2) MONTHS from the mail date of this decision. Any request not filed within two months of this decision may be dismissed as untimely. See 37 CFR 1.181(f). Extensions of time under 37 CFR 1.136(a) are NOT permitted. This is NOT a final agency action within the meaning of 5 U.S.C. § 704.

Any inquiry concerning this decision should be directed to Dean Reichard at (571) 272-1984. If attempts to reach the undersigned are unsuccessful, you may contact Brian Sircus at (571) 272-2058.

/Dean Reichard/
Dean Reichard, Quality Assurance Specialist
TC2800

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Smith, et al.

Application No.: 16/877,255

Filed: May 18, 2020

For: SOLAR CELLS WITH IMPROVED
LIFETIME, PASSIVATION AND/OR
EFFICIENCY

Examiner: Tran, Long K.

Art Unit: 2829

Confirmation No.: 2637

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

RENEWED PETITION UNDER 37 CFR §1.84(a)(2) TO ACCEPT COLOR DRAWINGS

Dear Examiner:

In reply to the Decision on Petition Under 37 CFR §1.84(a)(2) to Accept Color Drawings mailed June 28, 2021, Applicants hereby submit a renewed petition to accept color drawings in the above-referenced application. New Fig. 11 was drawn using grayscale, the only practical medium by which aspects of the claimed subject matter may be accurately conveyed. It is the only color figure submitted in this application. No new matter has been introduced.

Accordingly, Applicants request new Fig. 11 be accepted and the dismissal be vacated.

CONCLUSION

The Examiner is respectfully requested to contact the undersigned by telephone if it is believed that such contact would further the examination of the present application.

Pursuant to 37 C.F.R. 1.136(a)(3), the Applicant(s) hereby request and authorize the U.S. Patent and Trademark Office to (1) treat any concurrent or future reply that requires a petition for extension of time as incorporating a petition for extension of time for the appropriate length of time and (2) charge all required fees, including extension of time fees and fees under 37 C.F.R. 1.16 and 1.17, to Deposit Account No. 50-0393.

Respectfully submitted,

SCHWABE, WILLIAMSON & WYATT, P.C.

July 21, 2021

Date

1211 SW 5th, Ste. 1900
Portland, OR 97204
Telephone: (503) 222-9981
Facsimile: (503) 796-2900

/Justin K. Brask/

Justin K. Brask
Reg. No. 61,080

NEW SHEET

Example Process	Temp	Surface Dopant Conc.	Gettering Location	Surface Passivation	Lifetime	Efficiency
A	≤ 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	non-poly	2 fA/cm^2	$\sim 3 \text{ msec}$	Baseline
B	≤ 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	non-poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline
C	≤ 900 deg-C	$2 \times 10^{18} \text{ cm}^{-3}$	poly	2 fA/cm^2	$\sim 10 \text{ msec}$	+0.5 % abs.
D	≤ 900 deg-C	$4 \times 10^{18} \text{ cm}^{-3}$	poly	5 fA/cm^2	$\sim 10 \text{ msec}$	Baseline

Table 1. Example Processes for Solar Cell Fabrication

FIG. 11

Electronic Acknowledgement Receipt	
EFS ID:	43312915
Application Number:	16877255
International Application Number:	
Confirmation Number:	2637
Title of Invention:	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY
First Named Inventor/Applicant Name:	David D. Smith
Customer Number:	149776
Filer:	Justin K. Brask/Gigi Hoover
Filer Authorized By:	Justin K. Brask
Attorney Docket Number:	131815-255190_P167C2DC
Receipt Date:	21-JUL-2021
Filing Date:	18-MAY-2020
Time Stamp:	18:56:45
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		S1117US4_P167C2DC_renewed_petition_07212021.pdf	96288	yes	3
			eed4070b97194780d01cb69980e2070c44c2a9a2		

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	A petition from Applicant to accept Color Drawings or Color Photographs	1	2
	Drawings-only black and white line drawings	3	3
Warnings:			
Information:			
Total Files Size (in bytes):		96288	
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. <u>New Applications Under 35 U.S.C. 111</u> 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. <u>National Stage of an International Application under 35 U.S.C. 371</u> 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. <u>New International Application Filed with the USPTO as a Receiving Office</u> 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.			



UNITED STATES PATENT AND TRADEMARK OFFICE

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NOTICE OF ALLOWANCE AND FEE(S) DUE

149776 7590 09/29/2021
Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

EXAMINER

TRAN, LONG K

ART UNIT PAPER NUMBER

2829

DATE MAILED: 09/29/2021

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC	2637

TITLE OF INVENTION: SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1200	\$0.00	\$0.00	\$1200	12/29/2021

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

149776 7590 09/29/2021
Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC	2637

TITLE OF INVENTION: SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1200	\$0.00	\$0.00	\$1200	12/29/2021

EXAMINER	ART UNIT	CLASS-SUBCLASS
TRAN, LONG K	2829	136-256000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,

1 _____

(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☐ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies _____

4b. Method of Payment: (Please first reapply any previously paid fee shown above)

☐ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. Change in Entity Status (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment. **NOTE:** If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC	2637
149776 7590 09/29/2021 Schwabe Williamson & Wyatt/SunPower PACWEST CENTER, SUITE 1900 1211 SW FIFTH AVENUE PORTLAND, OR 97204			EXAMINER TRAN, LONG K	
			ART UNIT 2829	PAPER NUMBER
DATE MAILED: 09/29/2021				

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. 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 30 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, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. 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.

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 disclosure of these records is required by the Freedom of Information Act.
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 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.

Notice of Allowability	Application No. 16/877,255	Applicant(s) Smith et al.	
	Examiner LONG K TRAN	Art Unit 2829	AIA (FITF) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to Filing on 10/27/2020.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are 1-20. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some* c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. _____.

3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892) 2. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date <u>10/27/2020 and 12/10/2020</u> . 3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____. 4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____.	5. ☐ Examiner's Amendment/Comment 6. ☒ Examiner's Statement of Reasons for Allowance 7. ☐ Other _____.
---	--

/ LONG K TRAN/
Primary Examiner, Art Unit 2829

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.

Information Disclosure Statement

2. The Information Disclosure Statement filed on 10/27/2020 and 12/10/2020 have been considered.

Allowable Subject Matter

3. Claims **1 – 20** are allowed.

4. The following is an examiner's statement of reasons for allowance: Claims **1 – 20** are allowable over the prior art of record because none of the prior art whether taken singularly or in combination, especially when these limitations are considered within the specific combination claimed, to teach:

portion of the silicon substrate is formed at the back side of the solar cell and a first dielectric region formed over the silicon substrate, wherein the first dielectric region is formed over the front side of solar as recited in the independent claim **1**; and portion of the silicon substrate is formed at the front side of the solar cell; a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar; a first emitter region having metal impurities formed over the dielectric region as recited in the independent claim **10**.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

/LONG K TRAN/

Primary Examiner, Art Unit 2829

September 21, 2021

<i>Notice of References Cited</i>	Application/Control No. 16/877,255		Applicant(s)/Patent Under Reexamination Smith et al.	
	Examiner LONG K TRAN		Art Unit 2829	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20130247981-A1	09-2013	YELUNDUR; VIJAY	H01L31/02167	136/259
*	B	US-20100139763-A1	06-2010	Van Nieuwenhuysen; Kris	H01L31/1804	136/256
	C					
	D					
	E					
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	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

U.S. Patent and Trademark Office
PTO-892 (Rev. 01-2001)

Notice of References Cited

Part of Paper No. 20210916

Issue Classification 	Application/Control No. 16/877,255	Applicant(s)/Patent Under Reexamination Smith et al.	
	Examiner LONG K TRAN	Art Unit 2829	

CPC						
Symbol				Type	Version	
H01L	/	31	/	02008	F	2013-01-01
H01L	/	31	/	1804	I	2013-01-01
H01L	/	31	/	1864	I	2013-01-01
H01L	/	31	/	022441	I	2013-01-01
H01L	/	31	/	02167	I	2013-01-01
H01L	/	31	/	0745	I	2013-01-01
H01L	/	31	/	0747	I	2013-01-01
H01L	/	21	/	3221	I	2013-01-01
H01L	/	31	/	068	I	2013-01-01
H01L	/	31	/	186	I	2013-01-01
H01L	/	31	/	03682	I	2013-01-01
H01L	/	31	/	0368	I	2013-01-01
H01L	/	31	/	1872	I	2013-01-01
Y02E	/	10	/	547	A	2013-01-01
Y02P	/	70	/	50	A	2015-11-01

CPC Combination Sets						
Symbol			Type	Set	Ranking	Version
	/		/			

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	20	
/LONG K TRAN/ Primary Examiner, Art Unit 2829 (Primary Examiner)	21 September 2021 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 7

Issue Classification 	Application/Control No. 16/877,255	Applicant(s)/Patent Under Reexamination Smith et al.
	Examiner LONG K TRAN	Art Unit 2829

INTERNATIONAL CLASSIFICATION			
CLAIMED			
H01L		31	028
NON-CLAIMED			

US ORIGINAL CLASSIFICATION	
CLASS	SUBCLASS
257	79

CROSS REFERENCES(S)						
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	20	
/LONG K TRAN/ Primary Examiner, Art Unit 2829 (Primary Examiner)	21 September 2021 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 7

<i>Issue Classification</i> 	Application/Control No. 16/877,255	Applicant(s)/Patent Under Reexamination Smith et al.
	Examiner LONG K TRAN	Art Unit 2829

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47															
CLAIMS															
Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	20	
/LONG K TRAN/ Primary Examiner, Art Unit 2829 (Primary Examiner)	21 September 2021 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 7

<i>Search Notes</i> 	Application/Control No. 16/877,255	Applicant(s)/Patent Under Reexamination Smith et al.
	Examiner LONG K TRAN	Art Unit 2829

CPC - Searched*		
Symbol	Date	Examiner
H01L31/02008,1804,1872,1864,3068,022441	09/14/2021	LT

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner
257	79	09/14/2021	LT

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
H01L31/02008,1804,1872,1864,3068,022441.CPC. - Text Search	09/14/2021	LT
H01L31/028.IPCR. - Text Search	09/14/2021	LT
257/79 - Text Search	09/14/2021	LT
EAST Search	09/14/2021	LT
EAST Search	09/17/2021	LT
Interference Search	09/17/2021	LT

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
	US-PGPUB, USPAT - 1	09/17/2021	LT

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BIB DATA SHEET

CONFIRMATION NO. 2637

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.		
16/877,255	05/18/2020	136	2829 131	1815-255190_P167C2DC		
RULE						
APPLICANTS SunPower Corporation, San Jose, CA; INVENTORS David D. Smith, Campbell, CA; Tim Dennis, Canton, TX; Russelle De Jesus Tabajonda, Banlic Cabuyao City, PHILIPPINES; ** CONTINUING DATA ***** This application is a CON of 16/228,165 12/20/2018 PAT 10658525 which is a DIV of 15/876,927 01/22/2018 PAT 10170642 which is a CON of 15/213,273 07/18/2016 PAT 9899542 which is a CON of 14/579,935 12/22/2014 PAT 9520507 ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 05/26/2020						
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☒ No Verified and Acknowledged <u>/LONG K TRAN/</u> Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY CA	SHEETS DRAWINGS 6	TOTAL CLAIMS 20	INDEPENDENT CLAIMS 2
ADDRESS Schwabe Williamson & Wyatt/SunPower PACWEST CENTER, SUITE 1900 1211 SW FIFTH AVENUE PORTLAND, OR 97204 UNITED STATES						
TITLE SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY						
FILING FEE RECEIVED 1980	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit			

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S257	3	16/228165	US-PGPUB; USPAT; EPO; DERWENT	OR	ON	2021/09/17 16:18
S258	5	15/876927	US-PGPUB; USPAT; EPO; DERWENT	OR	ON	2021/09/17 16:20
S259	858	H01L31/02008,1804,1872,1864,3068,022441.CPC. AND emitter near region AND @AD<"20141222"	US-PGPUB; USPAT; EPO; DERWENT	OR	ON	2021/09/20 09:39
S260	0	S259 emitter with ((poly adj (Si Silicon)) polysilicon)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	AND	ON	2021/09/20 09:40
S261	13	S259 and first near emitter near region and second near emitter near region and side near3 solar near cell	US-PGPUB; USPAT	OR	ON	2021/09/20 09:41
S262	11	first near emitter near region and second near emitter near region and solar near cell and (first or second or top or bottom or upper or lower) near3 metal near3 contact (heat\$3 near3 silicon near3 substrate)	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 09:49
S263	95,791	((H01L31/02167 OR H01L31/022425).CPC. OR (438/72 OR 438/57).CCLS. OR (H01L31/18 OR H01L31/0232 OR H01L31/028).IPCR.)	US-PGPUB; USPAT; EPO;	OR	ON	2021/09/20 09:51

			DERWEN T			
S26 4	11	S263 and S262	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 09:51
S26 5	294,691	solar adj cell	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 09:59
S26 6	6,456	((("SMITH") near3 ("David"))) OR ((("DENNIS") near3 ("Tim"))) OR ((("TABAJONDA") near3 ("Russelle"))).INV.	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:00
S26 7	294,691	solar adj cell	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:02
S26 8	1,355	first adj emitter adj (region or area or layer)	US- PGPUB; USPAT; EPO; DERWEN T	AND	ON	2021/09/2 0 10:08
S26 9	44	(Dennis near3 tim).in.	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:11
S27 0	106	(Dennis near3 timothy).in.	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:11
S27 1	9	(Tabajonda near3 Russelle).in.	US- PGPUB; USPAT; EPO;	OR	ON	2021/09/2 0 10:11

			DERWEN T			
S27 2	0	S269 S270 S271	US- PGPUB; USPAT; EPO; DERWEN T	AND	ON	2021/09/2 0 10:12
S27 3	150	S269 S270 S271	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:12
S27 4	20	S273 and first near emitter near region and second near emitter near region and solar near cell and first and second	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:16
S27 5	20	S273 and first near emitter near region and second near emitter near region and solar near cell and first and second	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:17
S27 6	17,050	(Smith near3 David).in.	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:18
S27 7	6,991	((("SMITH") near3 ("David"))) OR (("DENNIS") near3 ("Tim")) OR (("TABAJONDA") near3 ("Russelle"))).INV.	US- PGPUB; USPAT; USOCR; EPO; JPO;	OR	ON	2021/09/2 0 10:18

			DERWEN T			
S27 8	14	(Tabajonda near5 Russelle).in.	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:18
S27 9	17,054	S276 S277 S278	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:18
S28 0	38	S279 and first near emitter near region and second near emitter near region and solar near cell and first and second	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:18
S28 1	38	S280	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:18
S28 2	523,658	solar near cell	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN	OR	ON	2021/09/2 0 10:23

			T; IBM_TDB			
S28 3	2,016	front near side near5 sun	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:24
S28 4	682	S282 S283	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	WITH	ON	2021/09/2 0 10:24
S28 5	538,060	solar near2 cell	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S28 6	8,503,23 9	substrate	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S28 7	1,764,57 5	(Si Silicon semiconductor) near3 S286	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN	OR	ON	2021/09/2 0 10:27

			T; IBM_TDB			
S28 8	71,215	S285 and S287	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S28 9	160,568	dop\$3 near2 concentration	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S29 0	98,207	S287 and S289	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S29 1	7,306	S288 and S290	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S29 2	15,654	emitter with impurity	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN	OR	ON	2021/09/2 0 10:27

			T; IBM_TDB			
S29 3	68,892	contact with emitter	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S29 4	7,412	S292 and S293	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:27
S29 5	303	S291 and S294	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:27
S29 6	1,346	H01L31/02008,1804,1872,1864,3068,022441 .CPC. AND emitter near region AND @AD<"20141222"	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	OR	ON	2021/09/2 0 10:29
S29 7	13	S296 AND first near emitter near region and second near emitter near region and side near3 solar near cell	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:29
S29 8	117	first near emitter near region and second near emitter near region and solar near cell and first and second	US- PGPUB; USPAT; EPO; DERWEN T	OR	ON	2021/09/2 0 10:31

S299	29	first near emitter near region and second near emitter near region and solar near cell and ((first or second or top or bottom or upper or lower or front or back) near3 metal near3 contact) ((dopant or dop\$3) near2 concentration) emitter	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 10:35
S300	29	first near emitter near region and second near emitter near region and solar near cell and (first or second or top or bottom or upper or lower) near3 metal near3 contact	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 10:36
S301	10	silicon near substrate dopant near concentration back near side solar near cell ((dielectric near region) and (front near side near solar))	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 10:51
S302	10	silicon near substrate dopant near concentration back near side solar near cell ((dielectric near region) and (front near side near solar))	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 10:51
S303	10	silicon near substrate dopant near concentration back near side solar near cell ((dielectric near region) and (front near side near solar)) emitter near region	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 10:55
S304	9	first near emitter near region and second near emitter near region and solar near cell and (first or second or top or bottom or upper or lower) near3 metal near3 contact and partial\$4.clm.	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 10:58
S305	10	silicon near substrate dopant near concentration back near side solar near cell ((dielectric near region) and (front near side near solar)) metal near contact	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 11:01
S306	10	silicon near substrate dopant near concentration back near side solar near cell ((dielectric near region) and (front near side near solar)) metal near contact emitt\$3 near region	US-PGPUB; USPAT; EPO; DERWENT	AND	ON	2021/09/20 11:02

S310	1	16/877255	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	AND	ON	2021/09/20 21:10
S313	425	solar near cell ((front near side with fac\$3 near3 sun) with (normal near operation))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	AND	ON	2021/09/20 21:12
S317	10	solar near cell ((front near side with fac\$3 near3 sun) with (normal near operation)) (silicon near substrate near5 dopant near concentration) (dielectric region with (front near side) with solar near cell)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	AND	ON	2021/09/20 21:26
S318	659	(dielectric near region with silicon near substrate)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	AND	ON	2021/09/20 21:30
S319	10	solar near cell ((front near side with fac\$3 near3 sun) with (normal near operation)) (silicon near substrate near5 dopant near concentration) (dielectric region with (front near side) with solar near cell) (dielectric near region with silicon near substrate)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	AND	ON	2021/09/20 21:30

S32 0	225	emitter near region metal near impurity	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:32
S32 1	225	emitter near region metal near impurities	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:32
S32 2	225	S320 or S321	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:33
S32 3	10	solar near cell ((front near side with fac\$3 near3 sun) with (normal near operation)) (silicon near substrate near5 dopant near concentration) (dielectric region with (front near side) with solar near cell) (dielectric near region with silicon near substrate) (emitter near region metal near impurities)	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:34
S32 4	10	solar near cell ((front near side with fac\$3 near3 sun) with (normal near operation)) (silicon near substrate near5 dopant near concentration) (dielectric region with (front near side) with solar near cell) (dielectric near region with silicon near substrate) (emitter near region metal near impurities) (metal near contact near5 emitter near region)	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:36

S32 5	10	S313 S324	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:37
S32 6	10	S313 S318 S324	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:37
S32 7	8	S326 (first near metal near contact with first near emitter near region)	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:47
S32 8	7	15/213273	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 21:51
S32 9	2	"9899542".pn.	US- PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN T; IBM_TDB	AND	ON	2021/09/2 0 22:01

S330	1	"9899542".pn.	US-PGPUB; USPAT	OR	ON	2021/09/21 09:35
S331	52	(US-20100105190-\$ US-20130247965-\$ US-20140166089-\$ US-20160126368-\$ US-20160181461-\$ US-20160268454-\$ US-20140166095-\$ US-7718888-\$ US-7737357-\$ US-8815634-\$ US-9269839-\$ US-9362426-\$ US-9520507-\$ US-20080217747-\$ US-20100084009-\$ US-20100304527-\$ US-20120305060-\$ US-20130247981-\$ US-20140061531-\$ US-20140166086-\$ US-20150162483-\$ US-20160056322-\$ US-20160155877-\$ US-20160197216-\$ US-20160240704-\$ US-20160240705-\$).DID.	US-PGPUB; USPAT; EPO; DERWENT	OR	ON	2021/09/21 10:25
S332	0	"2014360571".pn.	US-PGPUB; USPAT; EPO; DERWENT	OR	ON	2021/09/21 10:26
S333	2	"20140360571".pn.	US-PGPUB; USPAT; EPO; DERWENT	OR	ON	2021/09/21 10:27

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S334	18	first near emitter near region and second near emitter near region and solar near cell and (first or second or top or bottom or upper or lower) near3 metal near3 contact.clm.	US-PGPUB; USPAT	AND	ON	2021/09/21 10:40
S335	9	silicon near substrate dopant near concentration back near side solar near cell ((dielectric near region) and (front near side near solar)) metal near contact emitt\$3 near region.clm.	US-PGPUB; USPAT	AND	ON	2021/09/21 10:40

9/21/2021 10:45:16 AM

C:\Users\ltran4\Documents\EAST\Workspaces\16877255Huan.wsp

Receipt date: 10/27/2020

Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(Use as many sheets as necessary)</i>	<i>Complete if Known</i>	
	Application Number	16/877,255
	Filing Date	May 18, 2020
	First Named Inventor	Smith, David D.
	Group Art Unit	1757
	Examiner Name	Unassigned
Sheet 1 of 2	Attorney Docket No: 131815-255190_P167C2DC	

US PATENT DOCUMENTS					
Examiner Initial *	Cite No ¹	USP Document Number	Publication or Issue Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 7,718,888	05-18-2016	Cousins	
		US 7,737,357	06-15-2010	Cousins	
		US 8,815,631	08-26-2014	Cousins	
		US 9,269,839	02-23-2016	Lee, et al.	
		US 9,362,426	06-07-2016	Goto, et al.	
		US 9,520,507	12-13-2016	Smith, et al.	
		US-2008/0197454	08-21-2008	Rakotoniana, et al.	
		US-2008/0217747	09-11-2008	Chudzik, et al.	
		US-2010/0084009	04-08-2010	Carlson et al.	
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		US-2010/0139763	06-10-2010	Van Nieuwenhuysen, et al.	
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		US-2016/0240705	08-18-2016	Takahama	
		US-2016/0268454	09-15-2016	Gwon	

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No ¹	Foreign Patent Document Country Code/Number/Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ²
	15	JP 2011-166021 A	08-25-2011	Shin-Etsu Chemical Co Ltd		
	16	CN 102694077	09-26-2012	Lin, et al.		

EXAMINER

/LONG K TRAN/

DATE CONSIDERED 09/17/2021

Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449)
 * 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. † Applicant's unique citation designation number (optional) ‡ Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /L.K.T/

Receipt date: 10/27/2020

INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(Use as many sheets as necessary)</i>	<i>Complete if Known</i>	
	Application Number	16/877,255
	Filing Date	May 18, 2020
	First Named Inventor	Smith, David D.
	Group Art Unit	1757
	Examiner Name	Unassigned
Sheet 2 of 2	Attorney Docket No: 131815-255190_P167C2DC	

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No. 1	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 ²
	1	Pre-Interview Office Action for U.S. Patent Application No. 14/579,935 (Attorney Docket No. 131815-228875_P167) mailed January 11, 2016, 4 pgs.	
	2	International Search Report and Written Opinion from PCT/US2015/067220 (Attorney Docket No. 7923.P167PCT) mailed April 29, 2016, 13 pgs.	
	3	First Action Interview Pre-Interview Communication from U.S. Patent Application No. 15/213,273 mailed March 7, 2017, 7 pgs.	
	4	First Action Interview Office Action Summary from U.S. Patent Application No. 15/213,273 mailed May 23, 2017, 6 pgs.	
	5	International Preliminary Report on Patentability from PCT/US2015/067220 (Attorney Docket No. 131815-228879_P167PCT) mailed July 6, 2017, 11 pgs.	
	6	Extended European Search Report from European Patent Application No. 15874267.6 (Attorney Docket No. 131815-228878_P167EP) mailed March 9, 2018, 15 pgs.	
	7	Jan Bultman, et al. "Methods of emitter formation for crystalline silicon solar cells," 31 May 2010 (2010-05-31), XP055026905, Retrieved from the Internet, www.pv-tech.org, April 10, 2018, 12 pgs.	
	8	First Office Action for Chinese Application No. 2015800700209 (Attorney Docket No. 131815-228877_P167CN), issued August 31, 2018, 14 pgs.	
	9	First Action Interview Pre-Interview Communication from U.S. Patent Application No. 16/228,165 (Attorney Docket No. 131915-244905_P167C2D) dated April 8, 2019, 6 pgs.	
	10	Second Office Action from Chinese Patent Application No. 2015800700209 (Attorney Docket No. S1117CN_P167CN) mailed April 19, 2019, 12 pgs.	
	11	Examination Report from European Patent Application No. 15874267.6 (Attorney Docket No. P167EP_S1117EP) mailed April 30, 2019, 6 pgs.	
	12	First Action Interview from U.S. Patent Application No. 16/228,165 (Attorney Docket No. 131815-244905_P167C2D) dated July 12, 2019, 5 pgs.	
	13	Rejection Decision from Chinese Patent Application No. 2015800700209 (Attorney Docket No. S1117-CN) dated October 28, 2019, 9 pgs.	
	14	Reexamination Notice from Chinese Patent Application No. 2015800700209 (Attorney Docket No. S1117-CN) dated July 3, 2020, 12 pgs.	

EXAMINER	/LONG K TRAN/	DATE CONSIDERED	09/17/2021
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Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449)
* 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. Applicant's unique citation designation number (optional) 2 Applicant is to place a check mark here if English language Translation is attached

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /L.K.T/

Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(Use as many sheets as necessary)</i>	<i>Complete if Known</i>	
	Application Number	16/877,255
	Filing Date	May 18, 2020
	First Named Inventor	Smith, David D.
	Group Art Unit	2829
	Examiner Name	Unassigned
Sheet 1 of 1	Attorney Docket No: 131815-255190_P167C2DC	

US PATENT DOCUMENTS					
Examiner Initial *	Cite No ¹	USP Document Number	Publication or Issue Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
/L.K.T/		US 2014/360571	12-11-2014	Ji, et al.	

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No ¹	Foreign Patent Document Country Code/Number/Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ²

OTHER DOCUMENTS -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No ¹	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 ²
/L.K.T/		Official Communication from European Patent Application No. 15874267.6 (Attorney Docket No. S1117-EP) dated December 8, 2020, 15 pgs.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /L.K.T/

EXAMINER	/LONG K TRAN/	DATE CONSIDERED	09/17/2021
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Based on PTO/SB/08A(09-06) - Substitute Disclosure Statement Form (PTO-1449)
 * 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. Applicant's unique citation designation number (optional) 2 Applicant is to place a check mark here if English language Translation is attached

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COMMISSIONER FOR PATENTS
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ALEXANDRIA VA 22313-1451

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Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204



**Courtesy Reminder for
Application Serial No: 16/877,255**

Attorney Docket No:
131815-255190_P167C2DC
Customer Number: 149776

Date of Electronic Notification: 09/29/2021

This is a courtesy reminder that new correspondence is available for this application. If you have not done so already, please review the correspondence. The official date of notification of the outgoing correspondence will be indicated on the form PTOL-90 accompanying the correspondence.

An email notification regarding the correspondence was sent to the following email address(es) associated with your customer number:

IPDocketing@SCHWABE.com
ghoover@schwabe.com
mscardina@schwabe.com

To view your correspondence online or update your email addresses, please visit us anytime at **<https://ppair-my.uspto.gov/pair/PrivatePair>**. If you have any questions, please email the Electronic Business Center (EBC) at EBC@uspto.gov or call 1-866-217-9197.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC	2637
149776 7590 10/28/2021 Schwabe Williamson & Wyatt/SunPower PACWEST CENTER, SUITE 1900 1211 SW FIFTH AVENUE PORTLAND, OR 97204			EXAMINER TRAN, LONG K	
			ART UNIT 2829	PAPER NUMBER
			NOTIFICATION DATE 10/28/2021	DELIVERY MODE 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):

IPDocketing@SCHWABE.com
ghoover@schwabe.com
mcardina@schwabe.com

**UNITED STATES DEPARTMENT OF COMMERCE****U.S. Patent and Trademark Office**

Address: COMMISSIONER FOR PATENTS

P.O. Box 1450

Alexandria, Virginia 22313-1450

APPLICATION NO./ CONTROL NO.	FILING DATE	FIRST NAMED INVENTOR/ PATENT IN REEXAMINATION	ATTORNEY DOCKET NO.
16/877,255	05/18/2020	Smith et al.	131815-255190_P16

Schwabe Williamson & Wyatt/SunPower PACWEST CENTER, SUITE 1900 1211 SW FIFTH AVENUE PORTLAND, OR 97204		EXAMINER	
		LONG TRAN	
		ART UNIT	PAPER
		2829	20211025

DATE MAILED: _____

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

Commissioner for Patents

Please see the attached decision pertaining to the renewed petition to accept color drawings dated 21 July 2021.

/NATHAN MILAKOVICH/
Primary Examiner, Art Unit 2848

/DEAN A REICHARD/
TQAS, TC 2800



UNITED STATES PATENT AND TRADEMARK OFFICE

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P.O. Box 1450
Alexandria, VA 22313-1450
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Schwabe Williamson & Wyatt/SunPower
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

In re Application of: :
Smith *et al.* :
Serial No.: 16/877,255 :
Filed: May 18, 2020 : **DECISION ON PETITION**
Docket: 131815-255190_P167C2DC : **UNDER 37 C.F.R. § 1.84(a)(2) TO**
Title: SOLAR CELLS WITH IMPROVED : **ACCEPT COLOR DRAWINGS**
LIFETIME, PASSIVATION AND/OR
EFFICIENCY

This decision is in response to the renewed petition under 37 CFR 1.84(a)(2) for acceptance of color drawings, filed 21 July 2021.

The petition is **DISMISSED AS MOOT**.

Review of Facts

Applicant filed a petition requesting acceptance of color drawings on 21 July 2021.

Regulation and Practice

37 CFR 1.84(a)(2) states in part:

“The Office will accept color drawings in utility patent applications only after granting a petition filed under this paragraph explaining why the color drawings are necessary...Any such petition must include the following:

- (i) The fee set forth in 37 C.F.R. §1.17(h);
- (ii) One (1) set of the color drawings if submitted via the Office electronic filing system or three (3) sets of the color drawings if not submitted via the Office electronic filing system; and
- (iii) An amendment to the specification (unless the specification contains or has been previously amended to contain) the following language as the first paragraph of the brief description of the drawings:

“The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.”

MPEP 608.02(VIII) states in part:

“It is anticipated that such a petition will be granted only when the U.S. Patent and Trademark Office has determined that a color drawing or color photograph is the only practical medium by which to disclose in a printed utility patent the subject matter to be patented.”

Analysis and Decision

In accordance with 37 CFR 1.84(a)(2), the petition is deficient for the following reasons:

It does not appear that color drawings are present in the file wrapper.

The grayscale drawing submitted 21 July 2021 (FIG. 11, previously submitted 27 October 2020) is not a color drawing or color photograph. Therefore, a petition for acceptance of color drawings is not necessary in this application.

Accordingly, the petition is **DISMISSED AS MOOT.**

Any request for reconsideration of this decision must be submitted within TWO (2) MONTHS from the mail date of this decision. Any request not filed within two months of this decision may be dismissed as untimely. See 37 CFR 1.181(f). Extensions of time under 37 CFR 1.136(a) are NOT permitted. This is NOT a final agency action within the meaning of 5 U.S.C. § 704.

Any inquiry concerning this decision should be directed to Dean Reichard at (571) 272-1984. If attempts to reach the undersigned are unsuccessful, you may contact Brian Sircus at (571) 272-2058.

/Dean Reichard/
Dean Reichard, Quality Assurance Specialist
TC2800

“FEE ADDRESS” INDICATION FORM

Address to:
Mail Stop M Correspondence
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Fax to:
571-273-6500

- OR -

INSTRUCTIONS: The issue fee must have been paid for application(s) listed on this form. In addition, only an address represented by a Customer Number can be established as the fee address for maintenance fee purposes (hereafter, fee address). A fee address should be established when correspondence related to maintenance fees should be mailed to a different address than the correspondence address for the application. **When to check the first box below:** If you have a Customer Number to represent the fee address. **When to check the second box below:** If you have no Customer Number representing the desired fee address, in which case a completed Request for Customer Number (PTO/SB/125) must be attached to this form. For more information on Customer Numbers, see the Manual of Patent Examining Procedure (MPEP) § 403.

For the following listed application(s), please recognize as the “Fee Address” under the provisions of 37 CFR 1.363 the address associated with:

☒ Customer Number: 000197

OR

☐ The attached Request for Customer Number (PTO/SB/125) form.

PATENT NUMBER (if known)	APPLICATION NUMBER
	16/877,255

Completed by (check one):

☐ Applicant/Inventor	_____ /Justin K. Brask/ Signature
☒ Attorney or Agent of record <u>61,080</u> (Reg. No.)	Justin K. Brask _____ Typed or printed name
☐ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)	503-222-9981 _____ Requester's telephone number
☐ Assignee recorded at Reel _____ Frame _____	December 27, 2021 _____ Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☒ * Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.363. 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 5 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 COMPLETE D FORMS TO THIS ADDRESS. **SEND TO: Mail Stop M Correspondence, 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.

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 disclosure of these records is required by the Freedom of Information Act.
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 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.

Electronic Patent Application Fee Transmittal				
Application Number:		16877255		
Filing Date:		18-May-2020		
Title of Invention:		SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		
First Named Inventor/Applicant Name:		David D. Smith		
Filer:		Justin K. Brask/Gigi Hoover		
Attorney Docket Number:		131815-255190_P167C2DC		
Filed as Large Entity				
Filing Fees for Utility under 35 USC 111(a)				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1200	1200

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1200

Electronic Acknowledgement Receipt	
EFS ID:	44612574
Application Number:	16877255
International Application Number:	
Confirmation Number:	2637
Title of Invention:	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY
First Named Inventor/Applicant Name:	David D. Smith
Customer Number:	149776
Filer:	Justin K. Brask/Gigi Hoover
Filer Authorized By:	Justin K. Brask
Attorney Docket Number:	131815-255190_P167C2DC
Receipt Date:	27-DEC-2021
Filing Date:	18-MAY-2020
Time Stamp:	17:31:41
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$1200
RAM confirmation Number	E2021BQH32570356
Deposit Account	500393
Authorized User	Gigi Hoover
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)					
37 CFR 1.20 (Post Issuance fees)					
37 CFR 1.21 (Miscellaneous fees and charges)					
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Miscellaneous Incoming Letter	S1117US4_P167C2DC_Comments_on_Reasons_for_Allowance_12272021.pdf	17038	no	1
			6b91ee4b55438802e408862e4c7744a6f8e5b9b7		
Warnings:					
Information:					
2	Issue Fee Payment (PTO-85B)	S1117US4_P167C2DC_Issue_Fee_paid_12272021.pdf	162054	no	1
			ea983dbb8775955a7921223a16bee3fc0c51eb6f		
Warnings:					
Information:					
3	Maintenance Fee Address Change	S1117US4_P167C2DC_MFee_address_change_12272021.pdf	132504	no	2
			b586db78ec49ff104b9f672fc58a324229034606		
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	38308	no	2
			ed6236d50d1122cd73113140bccd5315a1f236da		
Warnings:					
Information:					
Total Files Size (in bytes):			349904		

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 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.

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 Application of:

Smith, et al.

Application No.: 16/877,255

Filed: May 18, 2020

For: SOLAR CELLS WITH IMPROVED
LIFETIME, PASSIVATION AND/OR
EFFICIENCY

Examiner: Tran, Long K.

Art Unit: 2829

Confirmation No.: 2637

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

COMMENTS ON EXAMINER'S STATEMENT OF REASONS FOR ALLOWANCE

Dear Examiner:

This is in response to the Notice of Allowance mailed September 29, 2021.

Applicants respectfully disagree with the Examiner's Statement of Reasons for Allowance to the extent that all the limitations recited by the Examiner are not present in all of the claims.

To the extent that there is any implication that the patentability of the claims rests on the recitation of a single feature, Applicants respectfully disagree with the Examiner's Statement because it is the combination of features that makes the claims patentable. Accordingly, Applicants submit that the claims of the present application are allowable because each of the claims recites a combination of features that are not taught or suggested by the prior art.

Respectfully submitted,
SCHWABE, WILLIAMSON & WYATT, P.C.

December 27, 2021

Date

PacWest Center
1211 SW Fifth Avenue
Suite 1900
Portland, OR 97204

/Justin K. Brask/

Justin K. Brask
Reg. No. 61,080

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

149776 7590 09/29/2021
Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

Gigi Hoover	(Typed or printed name)
/Gigi Hoover/	(Signature)
December 27, 2021	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/877,255	05/18/2020	David D. Smith	131815-255190_P167C2DC	2637

TITLE OF INVENTION: SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1200	\$0.00	\$0.00	\$1200	12/29/2021

EXAMINER	ART UNIT	CLASS-SUBCLASS
TRAN, LONG K	2829	136-256000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☒ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,

1 Schwabe, Williamson & Wyatt, P.C.

(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

SunPower Corporation

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

San Jose, CA

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies _____

4b. Method of Payment: (Please first reapply any previously paid fee shown above)

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 500393

5. Change in Entity Status (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29☐ Applicant asserting small entity status. See 37 CFR 1.27☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment. **NOTE:** If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Justin K. Brask/Date December 27, 2021Typed or printed name Justin K. BraskRegistration No. 61080



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/877,255	02/15/2022	11251315	131815-255190_P167C2DC	2637

149776 7590 01/26/2022

Schwabe Williamson & Wyatt/SunPower
PACWEST CENTER, SUITE 1900
1211 SW FIFTH AVENUE
PORTLAND, OR 97204

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment is 13 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

INVENTOR(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional inventors):

David D. Smith, Campbell, CA;
Tim Dennis, Canton, TX;
Russelle De Jesus Tabajonda, Banlic Cabuyao City, PHILIPPINES;

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

SunPower Corporation, San Jose, CA;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Smith, et al.

Patent No.: 11,251,315

Issue Date: February 15, 2022

For: SOLAR CELLS WITH IMPROVED
LIFETIME, PASSIVATION AND/OR
EFFICIENCY

Application No.: 16/877,255

Filing Date: May 18, 2020

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

REQUEST FOR CERTIFICATE OF CORRECTION

Dear Sir/Madam:

Enclosed is a Certificate of Correction for the above-identified Letters Patent.

This request for correction is made under the provisions of 37 C.F.R. 1.323. The fee for providing a certificate of correction is submitted herewith.

CONCLUSION

Pursuant to 37 C.F.R. 1.136(a)(3), the Applicant(s) hereby request and authorize the U.S. Patent and Trademark Office to (1) treat any concurrent or future reply that requires a petition for extension of time as incorporating a petition for extension of time for the appropriate length of time and (2) charge all required fees, including extension of time fees and fees under 37 C.F.R. 1.16 and 1.17, to Deposit Account No. 50-0393.

Respectfully submitted,

SCHWABE, WILLIAMSON & WYATT, P.C.

July 14, 2023

Date

1211 SW 5th, Ste. 1900
Portland, OR 97204
Telephone: (503) 222-9981
Facsimile: (503) 796-2900

/Justin K. Brask/

Justin K. Brask
Reg. No. 61,080

**UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION**Page 1 of 1

PATENT NO. : 11,251,315

APPLICATION NO.: 16/877,255

ISSUE DATE : February 15, 2022

INVENTOR(S) : Smith, et al.

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 10, line 58, insert -- the -- after "of", insert -- cell -- after "solar" and before the semicolon.

MAILING ADDRESS OF SENDER (Please do not use Customer Number below):

Schwabe, Williamson & Wyatt, P.C.
1211 SW 5th, Ste. 1900
Portland, OR 97204

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. 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 1.0 hour 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: Attention Certificate of Corrections Branch, 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.

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 disclosure of these records is required by the Freedom of Information Act.
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 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.

Electronic Patent Application Fee Transmittal				
Application Number:		16877255		
Filing Date:		18-May-2020		
Title of Invention:		SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY		
First Named Inventor/Applicant Name:		David D. Smith		
Filer:		Justin K. Brask/Gigi Hoover		
Attorney Docket Number:		131815-255190_P167C2DC		
Filed as Large Entity				
Filing Fees for Utility under 35 USC 111(a)				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
CERTIFICATE OF CORRECTION	1811	1	160	160

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				160

Electronic Acknowledgement Receipt	
EFS ID:	48298541
Application Number:	16877255
International Application Number:	
Confirmation Number:	2637
Title of Invention:	SOLAR CELLS WITH IMPROVED LIFETIME, PASSIVATION AND/OR EFFICIENCY
First Named Inventor/Applicant Name:	David D. Smith
Customer Number:	149776
Filer:	Justin K. Brask/Gigi Hoover
Filer Authorized By:	Justin K. Brask
Attorney Docket Number:	131815-255190_P167C2DC
Receipt Date:	14-JUL-2023
Filing Date:	18-MAY-2020
Time Stamp:	17:54:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$160
RAM confirmation Number	E20237DH55475425
Deposit Account	500393
Authorized User	Gigi Hoover
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)					
37 CFR 1.20 (Post Issuance fees)					
37 CFR 1.21 (Miscellaneous fees and charges)					
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Certificate of Correction	S1117US4_P167C2DC_Request_for_COC_07142023.pdf	161790	no	4
			19fdb441e611552bcb96fb25d52a9a30531f80aa		
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	38304	no	2
			0e78f99d6555f98bcd6f07d82ae51ea1db7af9b7		
Warnings:					
Information:					
Total Files Size (in bytes):			200094		
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. <u>New Applications Under 35 U.S.C. 111</u> 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. <u>National Stage of an International Application under 35 U.S.C. 371</u> 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. <u>New International Application Filed with the USPTO as a Receiving Office</u> 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.					

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 11,251,315 B2
APPLICATION NO. : 16/877255
DATED : February 15, 2022
INVENTOR(S) : Smith et al.

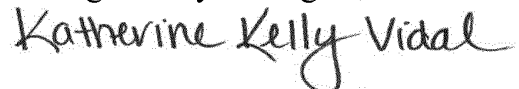
Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 10, Line 58, insert -- the -- after “of”, insert -- cell -- after “solar” and before the “;”.

Signed and Sealed this
Eighth Day of August, 2023



Katherine Kelly Vidal
Director of the United States Patent and Trademark Office