Paper No. 1

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CANADIAN SOLAR INC.,
Petitioner,

v.

MAXEON SOLAR PTE. LTD.
Patent Owner

Patent No. 8,878,053
Issued: November 4, 2014
Filed: June 13, 2012
Inventor: Peter John Cousins
Title: Front Contact Solar Cell with Formed Emitter
Inter Partes Review No. IPR2024-01040

PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 8,878,053

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Attachment B. List of Evidence and Exhibits Relied Upon in Petition

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I. INTRODUCTION

Canadian Solar Inc. ("CSI") respectfully requests that claims 9-20 of U.S. Patent 8,878,053 ("053 Patent") be cancelled as unpatentable. As demonstrated below, these claims are directed to well-known methods of making a backside junction solar cell disclosed years earlier by others, as modified by decades-old teachings that an *oxide layer* between a *polysilicon* backside emitter and the substrate would be beneficial to solar cell performance and efficiency.

For example, independent claim 9 of the 053 Patent claims *inter alia*, a method of fabricating a solar cell by first (a) forming a polysilicon layer on the back surface of the substrate, (b) forming a dopant source layer on the polysilicon layer, (c) diffuse dopants from a dopant source layer into the polysilicon layer to form a backside junction with the substrate, (d) diffuse dopants into the front surface, and (e) form metal contacts on the front surface. Yet years before the earliest effective filing date of the 053 Patent, a European Patent Publication to Froitzheim had already disclosed all these steps for making a backside junction solar cell, except that its backside emitter layer was part of the substrate rather than a deposited polysilicon layer. But this missing element was taught by numerous publications, including two prior art references relied upon here (Gan and Kwark). The Gan and Kwark prior art taught that solar cell performance can be improved by replacing the diffused emitter of Froitzheim's solar cell with a polysilicon

emitter having an interfacial oxide layer in between the substrate and polysilicon. Making this modification was well within the level of ordinary skill in the art and would have been obvious.

The other independent claim 16 is similar to claim 9 except that it explicitly recites forming an oxide layer before forming the polysilicon layer, which would also have been obvious in view of the same combination of prior art references.

The PTAB should institute this IPR because none of the prior art references relied upon in this Petition were considered by the Examiner during prosecution of the 053 Patent. And they address the specific deficiencies that the Examiner thought was in the prior art.

II. COMPLIANCE WITH REQUIREMENTS FOR A PETITION FOR INTER PARTES REVIEW

A. CSI Can Contest The 053 Patent

CSI certifies it is not barred or estopped from requesting *inter partes* review ("IPR") of the 053 Patent. Neither CSI, nor any party in privity with CSI, has filed a civil action challenging the 053 Patent's validity. The 053 Patent has not been the subject of any prior IPR. This IPR is filed within one year of the date of service of a complaint alleging infringement of the patent, and this patent is available for IPR.

B. IPR Fee (37 CFR §42.15(a)

The Director is authorized to charge the fee specified by 37 CFR §42.15(a) to Deposit Account No. 50-1597.

C. Mandatory Notices (37 CFR § 42.8(b))

CSI and Canadian Solar (USA) Inc. are the real parties in interest. The 053 Patent is involved in the following legal proceedings:

- *Maxeon Solar Pte. Ltd. v. Canadian Solar Inc.* 2-24-cv-00210 (ED Texas)
- *Maxeon Solar Pte. Ltd. v. Hanwha Energy Corporation et al,* 2-24-cv-00262 (ED Texas)
- *Maxeon Solar Pte. Ltd. v. REC Solar Holdings AS*, 2-24-cv-00260 (ED Texas)

Lead Counsel is Samuel N. Tiu (Reg. No. 47,997), stiu@sidley.com, 213-896-6095. Backup Counsel are Joseph Micallef (Reg. No. 39,772) jmicallef@sidley.com, 202-736-8492, and Brooke S. Böll (Reg. No. 76,268, brooke.boll@sidley.com, 213-896-6633.

Service on CSI may be made by email (Sidley-CSI-IPR@sidley.com), mail or hand delivery to: Sidley Austin LLP, 350 South Grand Avenue, Los Angeles, CA 90071. The fax number for lead and backup counsel is 213-896-6600.

Proof of service of this petition is provided in **Attachment A**.

III. IDENTIFICATION OF CHALLENGED CLAIMS

Claims 9-20 of the 053 Patent are unpatentable as follows:

1. Claims 9-11, 14, 16-17, and 19-20 were obvious based on Froitzheim and Gan;
2. Claims 11-13, 15 and 18 were obvious based on Froitzheim and Gan in view of Hartiti or Sivoththaman;
3. Claims 9-11, 14, 16-17, and 19-20 were obvious based on Froitzheim and Kwark;
4. Claims 11-13, 15 and 18 were obvious based on Froitzheim and Kwark in view of Hartiti or Sivoththaman;

Attachment B lists the evidence relied upon in this petition.

IV. PERSON OF ORDINARY SKILL IN THE ART

The person of ordinary skill in the art in the 053 Patent's field of solar cell design or manufacture in the 2008 ("Skilled Artisan") would have been someone with an advanced degree involving the discipline of electrical engineering, applied physics, chemistry, or materials science, and at least two years of experience designing, developing, or researching in the field. Alternatively, that person would have had a bachelor's degree in electrical engineering, applied physics, or materials science, and at least three years of experience designing, developing, or researching in the field. EX1003, ¶45.

V. CONTESTED PATENT OVERVIEW

A. Effective Filing Date

The 053 Patent was filed on June 13, 2012. It claims priority as a divisional to U.S. Patent No. 8,222,516, filed February 20, 2008. Thus, the earliest possible effective filing date is February 20, 2008.

B. Overview of the 053 Patent

The 053 Patent discloses a solar cell as shown in Figure 1.

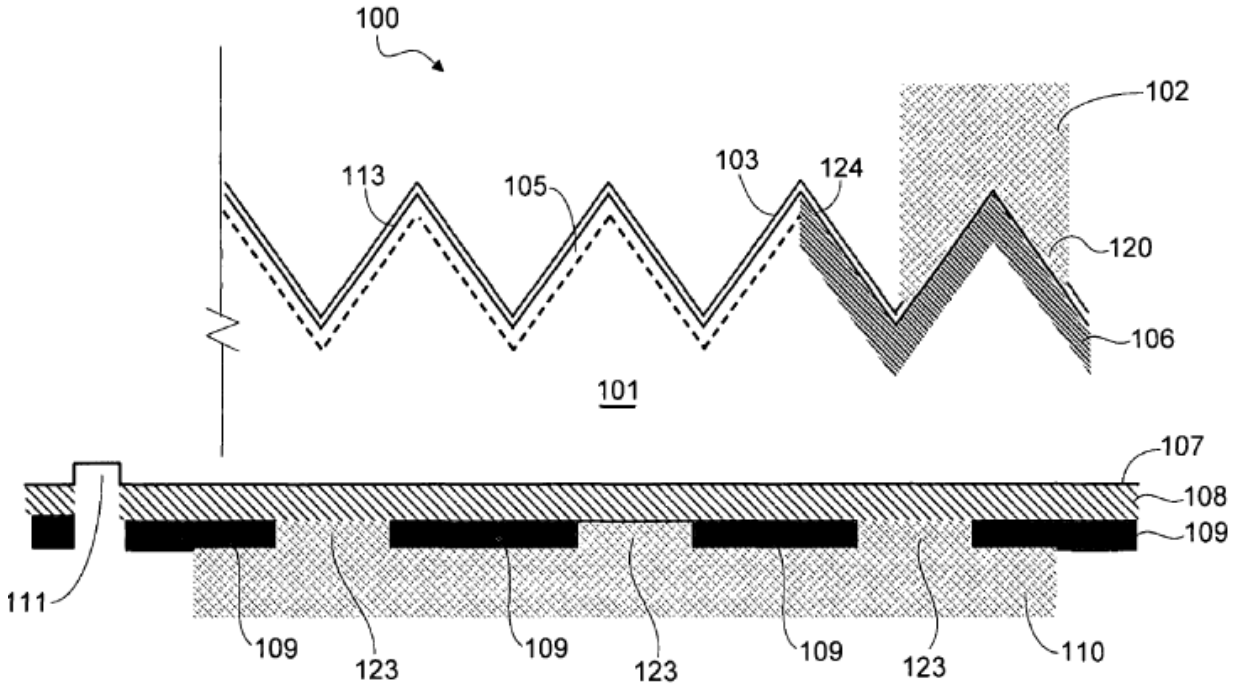


FIG. 1

The solar cell 100 includes an N-type silicon substrate 101. EX1001, 2:35-38. A "backside junction" is formed by the N-type substrate 101 and the P-type doped polysilicon emitter 108 formed at the solar cell's backside (bottom side of FIG. 1). EX1001, 2:35-38, 1:53-55. Between the polysilicon emitter 108 and the

substrate 101 is a tunnel oxide layer 107, which "may comprise silicon oxide thermally grown" on the substrate's surface. EX1001, 2:64-3:6. Backside metal contact 110 connects with the emitter 108 through contact holes 123 in the silicon dioxide layer 109. EX1001, 3:6-18. The solar cell's front side (top side of FIG. 1) has a texture 113 and a silicon nitride layer functioning as antireflective coating 103. EX1001, 2:29-34, 3:19-30, 4:36-41. Metal contact 102 connects with the substrate through holes in the antireflective coating 103. EX1001, 2:57-63.

Figures 4A-4M illustrate the solar cell's manufacturing process. EX1001, 3:56-58. This summary focuses on steps relevant to the claim limitations.

After the wafer/substrate is cleaned, tunnel oxides 107/402 are thermally grown on the front and back substrate surfaces, and polysilicon layers 108/401 are formed on the oxide layers by "CVD," i.e., chemical vapor deposition. EX1001, 4:4-13; EX1003, ¶52. Polysilicon layer 108 becomes the emitter in later steps. *Id.*

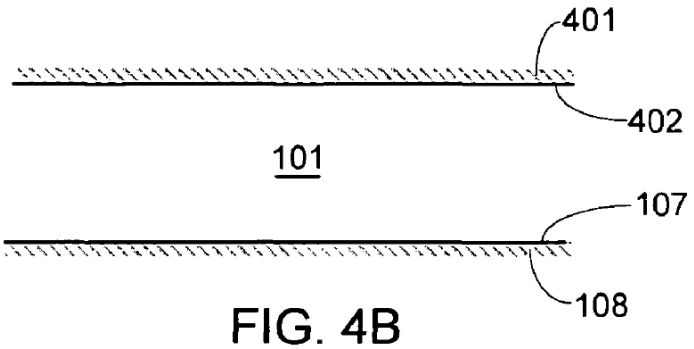


FIG. 4B

Subsequently, in preparation for doping the polysilicon layer 108, a p-type dopant source layer 461 such as BSG (borosilicate glass) is formed by atmospheric

pressure CVD ("APCVD") on the polysilicon layer 108 with an undoped silicon dioxide capping layer 462, as shown in FIG. 4C. EX1001, 4:14-27.

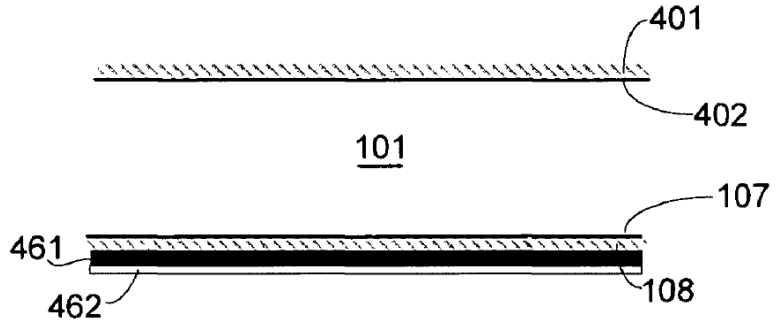


FIG. 4C

The front of the substrate then receives a texture 113, as seen in FIG. 4E. EX1001, 4:36-41.

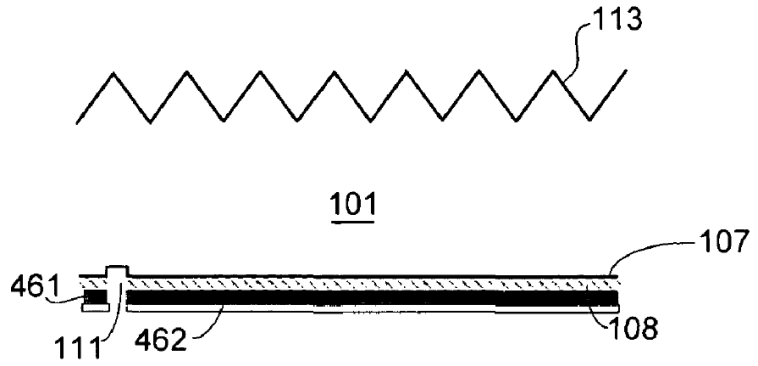


FIG. 4E

An N-type dopant source 412 is formed on the textured front surface 113. EX1001, 4:42-59. The N-type dopant source 412 can comprise "silicon dioxide doped with phosphorus." *Id.*, 4:51-52.

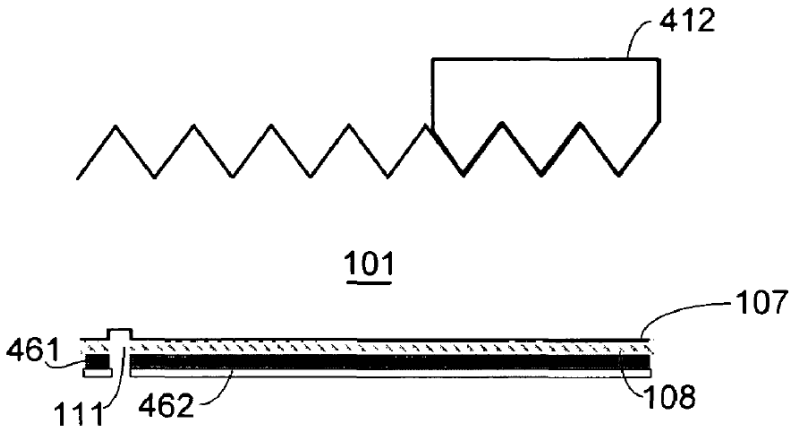


FIG. 4F

Subsequently, a "dopant drive-in" step is performed to diffuse dopants from the N-type dopant source 412 into the front surface and the P-type dopant source 461 into the backside polysilicon emitter 108, simultaneously. EX1001, 4:60-66.

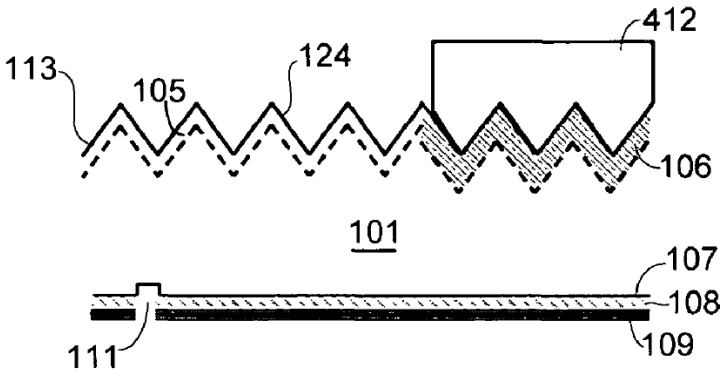


FIG. 4G

A silicon nitride antireflective coating 103 is then applied over the textured surface 113 after the N-type dopant source is removed. EX1001, 5:28-35.

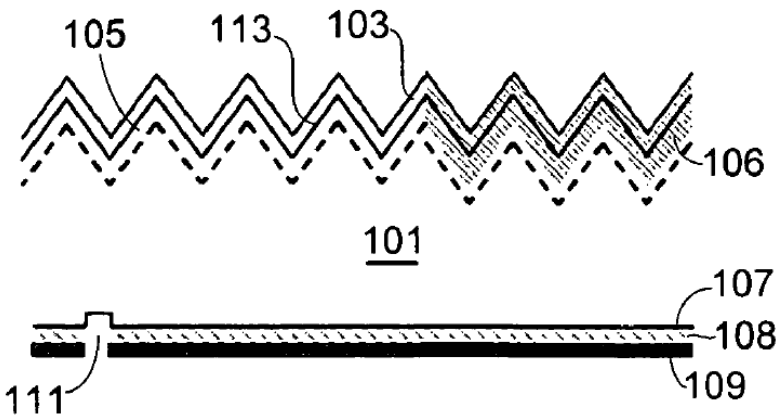


FIG. 4H

Afterwards, metal contacts 102 and 110 are formed on the front and back, respectively which includes creating contact holes 120/123 and then forming the contacts on the front and back side of the wafer over the contact holes. EX1001, 5:36-6:5. The metal contacts may be formed by screen-printing and firing. EX1001, 6:1-4.

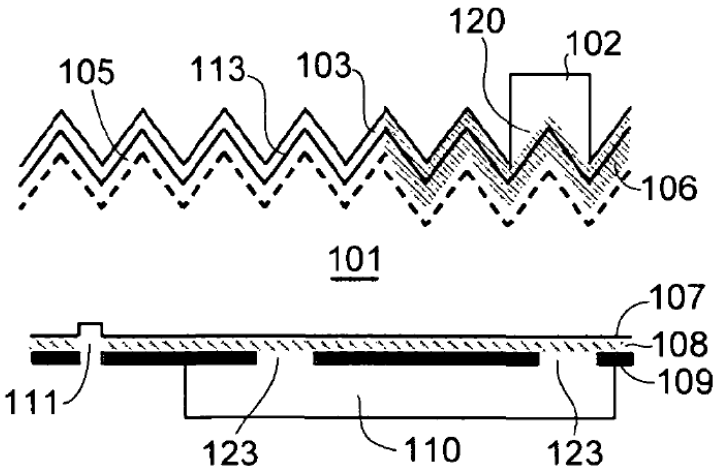


FIG. 4M

C. **The 053 Patent's Claims**

Independent claim 9 of the 053 Patent recites:

> *[9.a] A method of fabricating a solar cell comprising:*
>
> *[9.b] forming a layer of polysilicon over a back surface of a silicon substrate;*
>
> *[9.c] forming a first dopant source layer over the layer of polysilicon;*
>
> *[9.d] diffusing dopants from the first dopant source layer to the layer of polysilicon to form a backside junction with the silicon substrate;*
>
> *[9.e] diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and*
>
> *[9.f] forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.*

Independent claim 16 of the 053 Patent is similar to claim 9, except that additional includes a step of forming an oxide layer and omits the requirement of a "first dopant source layer." Claim 16 recites:

> *[16.a] A method of fabricating a solar cell comprising:*

[16.b] forming an oxide layer over a back surface of a silicon substrate;

[16.c] forming a layer of polysilicon over the oxide layer;

[16.d] diffusing dopants into the layer of polysilicon to form a backside junction with the silicon substrate;

[16.e] diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and

[16.f] forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.

D. <u>The 053 Patent's Prosecution History</u>

The 053 Patent is a divisional of U.S. Patent No. 8,222,516. Independent claims 9 and 16 of the 053 Patent were numbered application claims 21 and 28 during prosecution. During prosecution, claims 9 and 16 (application claims 21 and 28) initially recited all the elements as-issued except for "forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate." EX1002, 5.

The Examiner rejected the original application claim 21 over Meier (US6,262,359, EX1011) and Lindholm (EX1020), and original claims 21 and 28

over Smith288 (US6,998,288) (EX1024) and Lindholm. EX1002, 89-91. Meier disclosed an "Aluminum Alloy Back Junction Solar Cell" with a p-type emitter layer on the backside of an n-type substrate and an n-type doped layer on the front side. EX1011, Title, Abstract, 4:27-43. Smith288 disclosed a "back side contact solar cell" with both p-typed doped and n-type doped regions on the backside of the solar cell and metal contacts formed over them. EX1024, Abstract, FIG. 7. Lindholm disclosed "Heavily Doped Polysilicon-Contact Solar Cells" to "replace the conventional high-low junction or back surface-field (BSF) structure." EX1002, Abstract.

In response, the Applicant amended the claims to recite "forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate." EX1002, 125-29. The Applicant distinguished Smith288 as lacking "a metal contact on the front surface of the silicon substrate" because it is a backside contact solar cell, and "accordingly, Smith does not disclose a metal contact that connects to the substrate from the front side of the solar cell." EX1002, 131, 155-156.

As to Meier/Lindholm combination, the Applicant distinguished the combination as lacking a "diffusion of P-type dopants from the P-type dopant source to the layer of polysilicon" because "Meier teaches formation of a p+ layer 220 by epitaxial growth." EX1002, 130.

The Examiner then issued new rejections of application claim 21 over Silvestre (EX1021), Lindholm (EX1020), and Smith288 (EX1024) and of application claim 28 over Silvestre, Lindholm, and Swanson439 (EX1025). EX1002, 163-68. In response, the Applicant relied on the limitations "diffusing dopants from the first dopant source layer to the ***layer of polysilicon to form a backside junction with the silicon substrate***" and "diffusing dopants into the ***layer of polysilicon to form a backside junction with the silicon substrate***." EX1002, 217-219 (emphasis in original). The Applicant distinguished the claimed backside junction from a back surface field (BSF), stating: "As is well known, ***a BSF has the same dopant type as the substrate***, but at a higher concentration to keep minority charge carriers away from the back surface." EX1002, 217 (emphasis in original). The Applicant then argued that the Examiner's prior art combinations of Silvestre, Lindholm, and Smith288 or Swanson439 disclosed that "the polysilicon forms a BSF with the substrate, as opposed to a backside junction with the substrate." EX1002, 218-219. After the Examiner maintained his rejection, a pre-appeal brief was filed by the Applicant urging similar arguments. EX1002, 229-30, 232-37.

In a Notice of Panel Decision from Pre-Appeal Brief Review, the rejection was withdrawn and the claims were allowed, following Applicant's argument that a backside junction requires opposing dopant types and is distinct from a back

surface field that uses the same dopant type (but at a different concentration). EX1002, 244.

Notably, while the Examiner relied on Meier in the first rejection, the Examiner's second rejection did not start with or rely on Meier for its teaching of a back junction solar cell and backside junction, thereby allowing the Applicant to make the argument distinguishing backside junction from back surface field. EX1002, 163-68.

E. Known Technologies Not Considered by Examiner

Forming a backside junction solar cell by dopant diffusion in which the substrate and the backside emitter have opposite dopant polarities was already known by the Skilled Artisan before the effective filing date of the 053 Patent. For example, European Patent Publication No. EP1732142A1 by Froitzheim published in 2006 disclosed a back junction solar cell with a p-type doped emitter that forms a backside junction with the n-type doped substrate, and ***its emitter was formed by dopant diffusion***. EX1006, ¶¶25-26, 40; EX1003, ¶¶65, 84-85. Froitzheim was not considered by Examiner during prosecution. Froitzheim supplies the missing element of dopant diffusion that the Applicant used to overcome the back junction solar cell of Meier during prosecution. EX1002, 130. Froitzheim likewise supplies the "backside junction" element that the Applicant used to overcome Silvestre or Lindholm during prosecution.

Moreover, long before the effective filing date of the 053 Patent, those skilled in the art recognized that replacing diffused in-substrate emitters, such as the emitter in Froitzheim, with deposited polysilicon emitters would improve solar cell performance. For example, deposited polysilicon emitters with an interfacial oxide layer were first used to improve the performance of bipolar transistors in 1984. EX1003 ¶67 (citing EX1023, Ashburn 1984). "Interfacial oxide layer" refers to a thin layer of silicon oxide in between the substrate and the polysilicon emitter. EX1003 ¶67.

Around the same time, a number of publications suggested that this improvement with a polysilicon emitter can be achieved in solar cells as well. *See e.g.*, EX1016 (Yablonovitch), 597 ("There have been a considerable number of reports recently on improved bipolar transistor emitters made of polycrystalline silicon or of SIPOS (a mixture of microcrystalline silicon and silicon dioxide)…. Such heterojunctions are valuable not only for emitter efficiency in bipolar transistors, but also for solar cells"); EX1008 (Kwark), 742 ("Incorporation of these films into the emitter structure of an NPN bipolar transistor had been found to reduce the emitter saturation current fifty fold; this translates into potential improvements of energy conversion efficiency for solar cells and enhanced high frequency performance of bipolar structures."); EX1003, ¶¶67-68.

Subsequently in 1987, another publication noted that "[i]t is interesting to project what should be possible if the best available emitter technology were applied to point contact cells rather than the diffused emitters from the current process." EX1017, 2122. The authors modeled the projected efficiencies of what would be possible incorporating "SIPOS" emitters versus diffused emitters, and showed a more than one percent absolute increase in efficiency for the solar cell. EX1017, 2122; EX1003 ¶69.

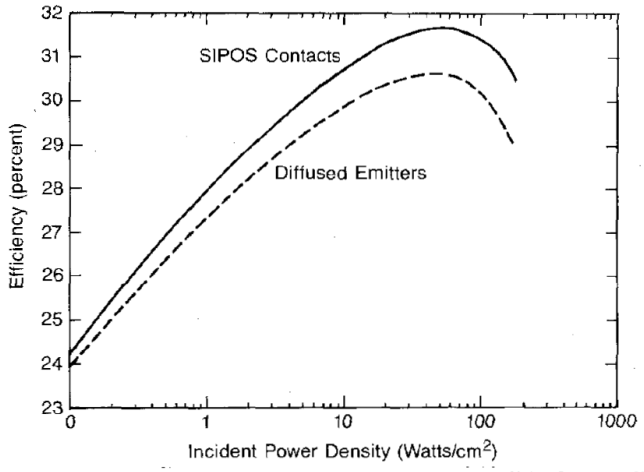


Fig. 9. A comparison of the projected efficiencies possible for a cell incorporating SIPOS emitters (solid curve), compared to projections for diffused emitters as used to date (dashed curve).

"SIPOS" refers to "semi-insulating polysilicon," which are formed by introducing a small amount of oxygen bearing species into the chemical vapor deposition of polysilicon. EX1003, ¶70. But as researchers have found in 1984, even a pure polysilicon emitter layer with a separate chemically formed interfacial oxide layer led to "surprising" improvement. EX1008, 84; EX1003, ¶70.

Following these suggestions, Gan (detailed below) examined the use of polysilicon emitters with a separate interfacial oxide layer in concentrator solar cells in 1990 and noted that the "cell performance can be improved if the diffused-emitter is replaced with the polysilicon emitter." EX1007, 245. Gan also pointed to the earlier 1987 modeling showing one percent absolute increase in solar cell efficiency for a "backside contact solar cells." Backside contact solar cells have their PN junction (i.e., junction with opposite p and n polarity) at the back of the solar cells. EX1003, ¶70.

A month before the earliest possible effective filing date of the 053 Patent, Peter Borden of Applied Materials filed a provisional application disclosing polysilicon emitter solar cells with an interfacial oxide layer, which also appears in the later filed PCT application:

> The present invention relates to improved HIT type or polysilicon emitter solar cells. According to certain aspects, the invention includes forming a masking oxide layer on the front and back of the cell and then patterning holes in the masking oxide. A HIT cell structure or polysilicon emitter solar cell structure is then formed over the patterned oxide, …. EX1010, Abstract; EX1009, Abstract.

None of these prior art references were before the 053 Patent Examiner.

VI. DISCRETIONARY DENIAL IS INAPPLICABLE

The PTAB should <u>*not*</u> deny institution based on Section 325(d) because none of the obviousness combinations or references relied on here were presented during

the 053 Patent's prosecution. These references disclosed what the Examiner thought was missing in the prior art during the 053 Patent prosecution.

The factors set forth in *Apple Inc. v. Fintiv, Inc.*, IPR2020-00019, Paper 11 at 5-6 (PTAB Mar. 20, 2020) also weigh against discretionary denial of institution:

Factor 6: The merits here are compelling and require institution per the Director's June 21, 2022 memo. EX1026 at 2. The combinations presented are straightforward insertion of known process steps into the fabrication of a known back junction solar cell to yield results already predicted by the prior art. Indeed, when presented with the right prior art combinations that start with a back junction solar cell combined with and modified by polysilicon emitter prior art not considered during the 053 prosecution, the PTAB in two decisions affirmed the Examiner's rejections of the corresponding device claims as being obvious. *See* §XIV below. CSI uses a similar analysis here with the method claims.

Factors 1&2: Maxeon filed suit on March 25, 2024 against CSI in the Eastern District of Texas. The Texas court has not held a scheduling conference nor set a trial date as of this IPR's filing. The presiding Judge Gilstrap has also frequently granted stays based on instituted IPRs, with at least 48 stays granted and only 41 denied with prejudice. EX1027.

Furthermore, a recent study confirmed that in over 94% of cases, future trial dates considered by the PTAB in its *Fintiv* analysis do not hold. EX1028. As

Senator Tillis has written to Acting Director Hirshfeld, "the PTAB 's historical practice of crediting unrealistic trial schedules … has not only produced outcomes that are untethered from the policy underpinnings of the *Fintiv* rule, but [] has also created harmful incentives for forum shopping and inappropriate judicial behavior." EX1029, 1.

Factor 3: CSI filed this Petition expeditiously, less than three months after Maxeon's complaint, which favors institution. *SK Hynix Inc. v. Netlist, Inc*., IPR2020-01042, Paper 14, 14 (PTAB Dec. 17, 2020). By the time an institution decision will be made, little or no substantive proceedings will have occurred in the parallel litigation. It is likely that initial contentions will be exchanged and possibly some Markman briefing will take place. But it is unlikely that substantial investment in the court proceeding will have occurred on invalidity.

Factor 4: CSI stipulates that, if this IPR is instituted, it will not assert in any district court or ITC litigation that any claim at issue in this IPR is invalid on the basis of any ground raised or reasonably could have been raised during this IPR.

Factor 5: CSI is one of the defendants in the district court cases, a fact that should weigh against denial because it permits CSI to provide the §315 stipulation above, thereby avoiding any possibility of duplication.

VII. CLAIM CONSTRUCTION

CSI submits that the term "in situ" in dependent claim 15 is appropriate for construction because it is defined in the 053 Patent. CSI's proposed construction is described in association with analysis of claim 15. §X.5. CSI does not believe that other constructions are necessary to resolve this Petition.

VIII. OVERVIEW OF THE PRIOR ART

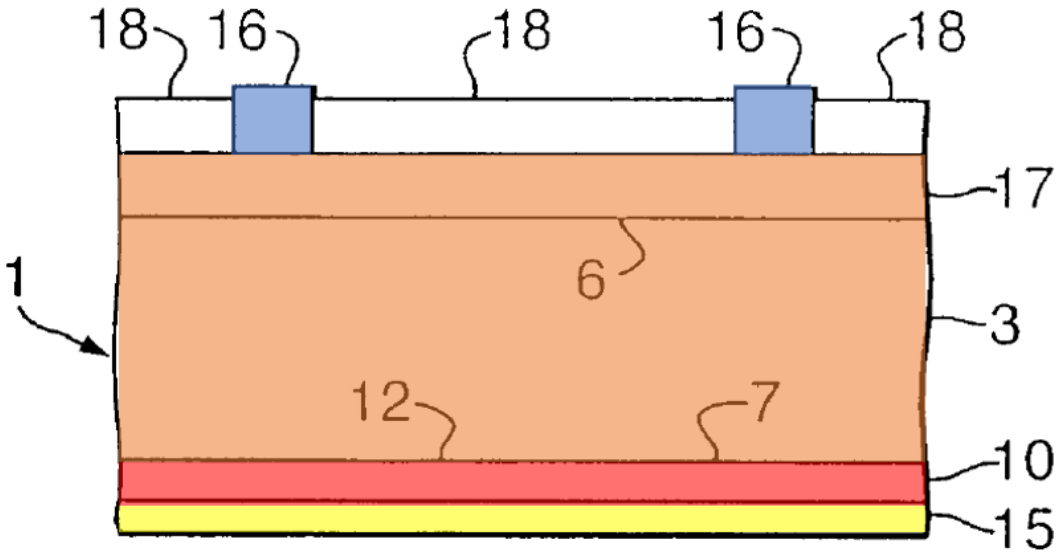
Back junction solar cells and polysilicon emitters with interfacial oxide layers were well known in the art before February 20, 2007. For example, Froitzheim (discussed below) disclosed a back junction solar cell and the process for making such cell. Gan and Kwark (discussed below) both disclosed polysilicon emitters with interfacial oxide layers, and the process for making them. It would have been obvious to combine the polysilicon emitter and interfacial oxide layer of Gan and Kwark with the back junction solar cell of Froitzheim as the prior art taught to do. EX1003, ¶82.

A. <u>EP1732142A1 to Froitzheim (EX1006)</u>

EP1732142A1 ("Froitzheim") was filed June 6, 2005 and published on December 13, 2006. EX1006, face. It is prior art under 35 U.S.C. §102(b).[1]

[1] Each citation in this Petition to 35 U.S.C. §102 refers to the pre-AIA version of that statute.

Froitzheim explained that in conventional solar cells, the n-type emitter is placed at the front of the cell to form a PN junction with an oppositely doped p-type substrate. EX1006, ¶2; EX1003, ¶84. However, Froitzhem proposed to instead place the emitter/PN junction at the rear side of the solar cell, and thus forms a backside junction solar cell. EX1006, ¶8; EX1003, ¶84. Froitzheim's Figure 1, shown below, is a solar cell 1 having an N-type body layer or substrate 3 with a front side 6 and a rear side 7. EX1006, ¶24.



To fabricate this solar cell, Froitzheim starts with an n-type silicon substrate and etched the front surface "to texture the surface in order to improve the geometry of incidence of light in order to prevent reflection." EX1006, ¶39; EX1003, ¶85. Unlike the Meier reference distinguished during the 053 Patent prosecution, Froitzheim explicitly taught diffusion of boron, a p-type dopant, into the substrate's rear surface. EX1006, ¶40. This diffused p-type doped layer 10

forms a backside junction with the oppositely doped n-type substrate. EX1003, ¶85. The boron is diffused from a "diffusion source layer that contains boron" and is "applied e.g., spun, only onto the back of the n-doped silicon wafer." EX1006, ¶41. As was well known in the art, such spun on boron diffusion source forms a borosilicate glass from which the boron is thermally driven into the silicon. EX1003, ¶85; EX1006, ¶42; EX1030 (Nolan).

On the front side, phosphorus (an n-type dopant) is diffused onto the front surface of the substrate. EX1006, ¶¶43-44.

Afterwards, passivation and anti-reflection coating are applied "using known methods," and front and rear metal contacts are screen-printed and fired. EX1006, ¶48-50, 60.

B. <u>Gan (EX1007)</u>

Gan et al., "Polysilicon Emitters for Silicon Concentrator Solar cells," Proceedings of the 21st IEEE-PVSC ("Gan") was a paper presented in 1990 (EX1007, face, ii-iii) and the paper was published by at least 1994 and no later than August 6, 2002 when it was publicly available electronically for download from *IEEE Xplore,* and in any event was publicly available before February 20, 2007. EX1032, ¶¶6, 29, 73-79; EX1046. Gan was widely distributed and has been known and cited by others in the field by at least 1994, further confirming its public dissemination before February 20, 2007. EX1032, ¶79; EX1047; EX1048.

EX1007 is an authentic copy of Gan that was published before February 20, 2007. EX1032, ¶¶6, 73-79. Thus, it is prior art under 35 U.S.C. §102(a) and (b).

Gan examined "polysilicon emitters with a thermally grown interfacial oxide" for solar cells in "great detail." EX1007, 245. Gan disclosed that "a very thin oxide (interfacial oxide)" "always exists" between the polysilicon emitter and substrate, "which can be as a by-product of the cleaning process or is grown intentionally." EX1007, 245. Gan explicitly suggested that solar "cell performance can be improved if the diffused-emitter [*i.e.*, an emitter doped into the substrate, as in Froitzheim] is replaced with the polysilicon emitter,…" EX1007, 245; EX1003, ¶88. Before depositing the polysilicon layer, Gan first formed an oxide layer on the silicon substrate. EX1007, 246 (Steps 1-3); EX1003, ¶88.

Gan experimented with thin interfacial oxides typically less than 20 Angstroms. EX1003, ¶88 citing EX1007, 246. Gan also tested both n- and p-type emitters. EX1007, Figs. 4-5, 249.

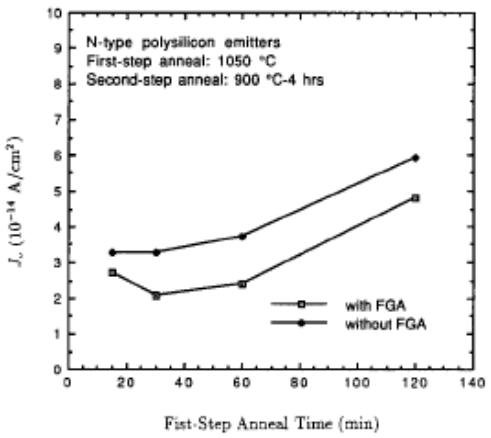


Figure 4: The J_o versus the first-step anneal time for n-type polysilicon emitters.

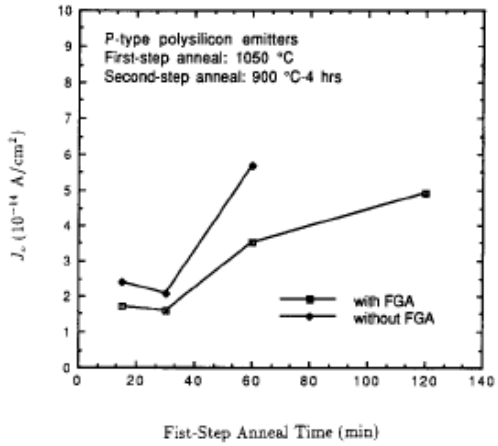


Figure 5: The J_o versus the first-step anneal time for p-type polysilicon emitters.

Gan observed better J_o results with the "use of thermal oxide as the interfacial layer in our samples." EX1007, 248; EX1003, ¶92. Gan concluded that "polysilicon emitters with low J_o and ρ_c can be obtained with a very small fraction of interfacial oxide breakup."[2] EX1007, 249. Gan taught that "polysilicon emitters with these qualities can be quite useful for silicon concentrator solar cells." EX1007, 249. Citing to the early work by Sinton, Gan further noted that "more than one absolute percent of the cell efficiency is obtained for backside contact solar cell with polysilicon emitters with characteristics shown here …." *Id.*

[2] J_o measures reverse saturation current density, and ρ_c measures resistivity of the contact. EX1003, ¶89. A lower Jo number indicates a lower recombination that tends to improve solar cell performance. *Id*. A lower ρ_c indicates lower contact resistance, which, in turn, leads to lower solar cell series resistance, improved fill factor and higher efficiency. *Id*.

Backside contact solar cells were known to have their PN junction on the backside of the solar cells. EX1003, ¶89.

In its process, Gan first formed the silicon oxide layer over the substrate by oxidation of the silicon substrate in steps 1 and 3, followed by the deposition of the polysilicon layer in step 4, as shown in the process steps reproduced below from Gan. EX1007, 246; EX1003, ¶90.

1. Field oxidation (2000 Å)*.
2. Polysilicon-substrate contact opening*.
3. Thin thermal oxide growth at 800 °C*. (10-minute oxygen flow)
4. Polysilicon deposition (6000 Å) and first-step anneal (1050 °C)*.
5. First-step anneal *.
6. Polysilicon finger definition.
7. Undoped glass deposition (2000 Å).
8. Metal-polysilicon and metal-substrate contact opening.
9. Doped glass deposition on both sides of the wafer*.
10. Drive-in; 900-1000 °C*.
11. Doped glass stripping and Al-1% Si alloy deposition.
12. Metal finger definition.

As shown, the dopants are diffused (i.e., "drive[n]-in") from diffusion sources of "doped glass" layers deposited on both sides of the wafer in steps 9 and 10. EX1003, ¶90. And then metal contacts are then formed on both sides in steps 11 and 12. EX1003, ¶90.

C. **Kwark (EX1008)**

Kwark et al. "SIPOS Heterojunction contacts to silicon," International Electron Devices Meeting (1984): 742-745 ("Kwark") was a paper presented in 1984 (EX1008, face, viii) and the paper was published at least by 1986 but no later than August 9, 2005 when it was made publicly available for electronic download at IEEE Xplore, and in any event was publicly available before February 20, 2007. EX1032, ¶¶6, 29, 52-58; EX1043; EX1044. Kwark was widely distributed and has also been known and cited by others in the field by at least 1997, including in a US Patent that issued in 1997, further confirming its public dissemination before February 20, 2007. EX1032, ¶58; EX1045. Exhibit 1008 is an authentic copy of Kwark that was published before February 20, 2007. EX1032, ¶¶6, 52-58. Thus, it is prior art under 35 U.S.C. §102(a) and (b).

Kwark (even earlier than Gan) tested polysilicon films with and without an intervening chemically grown oxide layer, and found that the oxide layer greatly decreased emitter saturation current—a characteristic Kwark noted translates into potential improvements for solar cell efficiency. EX1008, 742; EX1003, ¶92. Kwark reported that addition of "POLY" (*i.e.*, pure polysilicon emitter) *without* the "chemox" (*i.e.*, chemically formed oxide layer) "does not greatly impact J_{oe} as would be expected" where J_{oe} was a measure of emitter saturation current and solar cell recombination. EX1008, 743; EX1003, ¶92. However, *when the chemically*

formed oxide layer was present, it "greatly decrease[d] the J_{oe} as has been previously reported" which is beneficial to solar cell. EX1008, 743; EX1003, ¶92. Kwark illustrated this decrease in J_{oe} with the "chemox" in Figure 4:

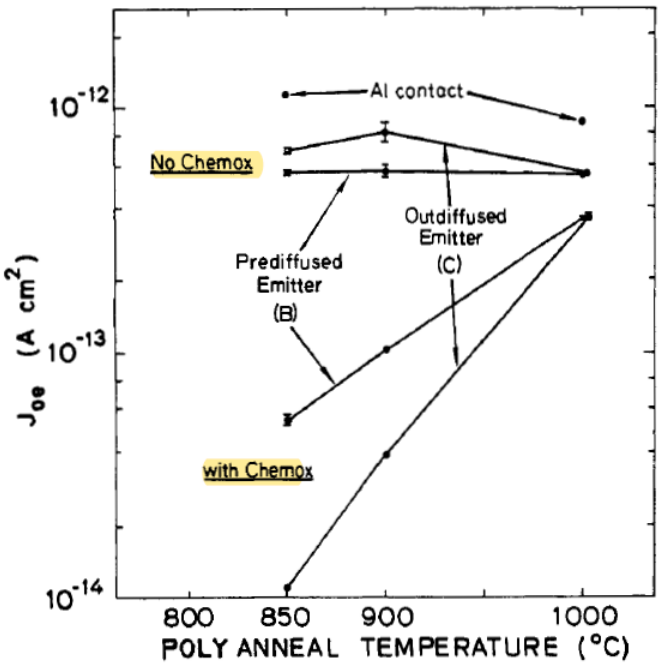
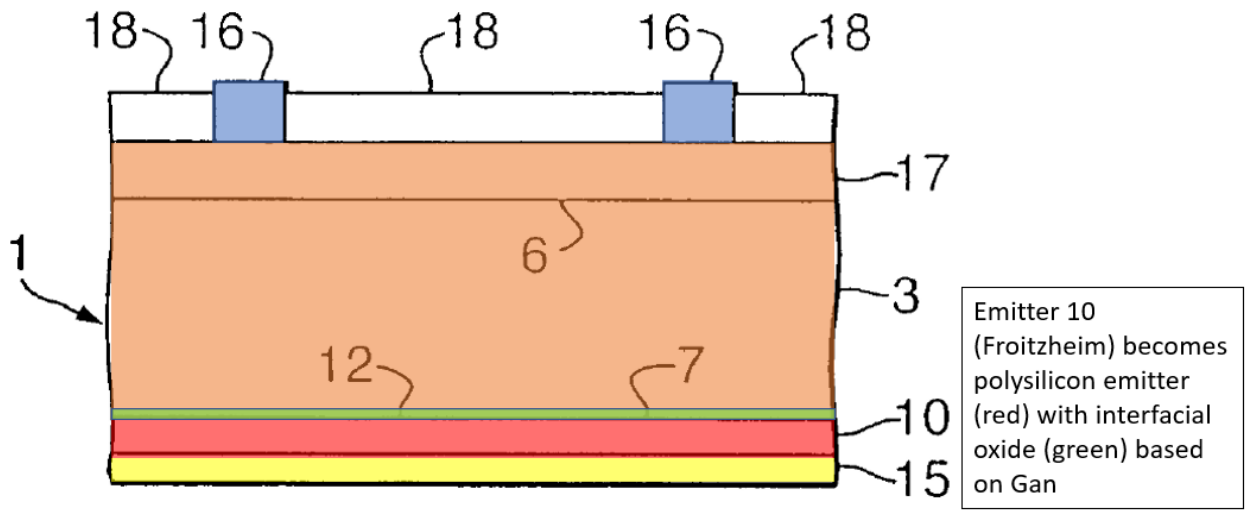


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

Based on Gan and Kwark's teachings, it would have been obvious to the Skilled Artisan to replace Froitzheim's p-type in-substrate emitter with a p-type *polysilicon* emitter along with an interfacial oxide layer between the emitter and the substrate, as taught by Gan and Kwark. EX1003, ¶¶93-105, 156-161.

IX. CLAIMS 9-11, 14, 16-17, AND 19-20 ARE UNPATENTABLE OVER FROITZHEIM AND GAN

The combination Froitzheim and Gan would have rendered Claims 9-11, 14, 16-17, and 19-20 obvious and unpatentable. To improve upon the back junction solar cell of Froitzheim, the Skilled Artisan would have replaced the p-type *diffused* in-substrate emitter of Froitzheim with a p-type deposited *polysilicon* emitter and an interfacial oxide layer, as taught by Gan. The resulting modified solar cell is illustrated below using a modified Froitzheim Fig. 1 for illustration. EX1003, ¶93. The combination would be nothing more than inserting the steps of forming the oxide layer and polysilicon emitter in Gan on the backside of the substrate into Froitzheim's fabrication process before dopant application and diffusion; and thereafter diffusing the same p-type dopants from a boron diffusion source as in the manufacturing of Froitzheim's solar cell. *Id*. This would form a backside junction polysilicon emitter with an interfacial oxide layer rather than a diffused in-substrate emitter layer. *Id*.



A. <u>Motivation to Modify Froitzheim with Gan</u>

Froitzheim and Gan are analogous art because each is in the same field of endeavor—solar cell design. EX1003, ¶94; EX1006, Abstract, ¶¶1,9; EX1007, 245, 249. Each is reasonably pertinent to the problems of efficiencies and cost-effectiveness of solar cell designs. EX1003, ¶94; EX1006, Abstract, ¶¶1,9; EX1007, 245, 249.

The Skilled Artisan would have been motivated to replace Froitzheim's diffused emitter with a deposited polysilicon emitter along with an oxide layer because Gan taught and suggested that this modification would be an improvement. EX1003, ¶95. Gan disclosed that "***the cell performance can be improved if the diffused-emitter [e.g., of Froitzheim] is replaced with the polysilicon emitter***…." EX1007, 245. As to the oxide layer, Gan noted that "the J_o [i.e., measure of surface recombination] of the p-type polysilicon emitter (Fig 5)

[beneficially] appears to be much lower than what has been previously reported," and suggested that it "may have to do with the use of thermal oxide as the interfacial layer in our samples." EX1007, 248. Gan explained that "because the dominant recombination is likely at the oxide interface, it implies that the oxide must only be broken by a very small fraction, which is consistent with what was observed in Fig. 2." EX1007, 248; EX1003, ¶95.

Gan provided lowered J_o and ρ_c data in Figure 6 and concluded the characteristics brought about by the polysilicon emitter with interfacial oxide layer structure is "***quite useful for silicon solar cells***." EX1007, 249. Froitzheim likewise used silicon solar cells. EX1006, Abstract. Gan further pointed to prior modeling and determined that "***more than one absolute percent of the cell efficiency is obtained for a backside contact solar cell with polysilicon emitters*** with characteristics shown here …." EX1007, 249. Gan's calculations are in the context of a backside contact solar cell which, like Froitzheim, would place the emitter and PN junction on the backside of the solar cell, which would further suggest the combination. EX1003, ¶96.

While Gan referred in part to silicon concentrator solar cells, it more broadly suggested that a polysilicon emitter with interfacial oxide is "quite useful for silicon solar cells" generally (EX1007, 249), and the Skilled Artisan would interpret Gan as recommending the feature for solar cells in general. EX1003, ¶97.

Gan also disclosed that the benefits apply to both n- and p-type polysilicon emitters, including those formed on the back side of the solar cell, and thus would have suggested replacing Froitzheim's rear p-type diffused *in-substrate* emitter with a rear p-type deposited *polysilicon* emitter plus the beneficial interfacial oxide layer. EX1007, 249 (discussing "both n- and p-type polysilicon emitters."); EX1003, ¶97.

A Skilled Artisan would further have been motivated specifically to leave the emitter on the back side of the solar cell because Froitzheim disclosed that its design "shows improved stability and good efficiency." EX1006, ¶9. As Dr. Banerjee explains, it was well known that back junction solar cells often lead to higher solar cell efficiency than front junction cells. EX1003, ¶98. In the combination, Froitzheim's modified emitter would continue to function as before, but with the expected additional improvement provided by the polysilicon emitter and interfacial oxide layer. EX1003, ¶98. And replacing the diffused emitter with the polysilicon emitter and interfacial oxide layer, as taught by Gan, merely substitutes one element for another already known in the field, yielding a predictable result. EX1003, ¶98. *See also*, *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 416 (2007).

Aside from Gan, numerous other prior art references taught the inclusion of an interfacial oxide layer when replacing a diffused emitter with a polysilicon

emitter. EX1003, ¶¶99-100. For example, as discussed in §§V.E, IX.A, the Skilled Artisan would have further been motivated because Kwark taught that addition of an interfacial chemically grown oxide (chemox) between polysilicon and the substrate "greatly decreases the J_{oe}," which "translates into potential improvements of energy conversion efficiency for solar cells." EX1008, 742, 745; EX1003, ¶100. Kwark provided data comparing polysilicon emitters with and without the oxide layer, and noted "the large difference when the interfacial oxide is missing." EX1008, 745 Fig. 4.

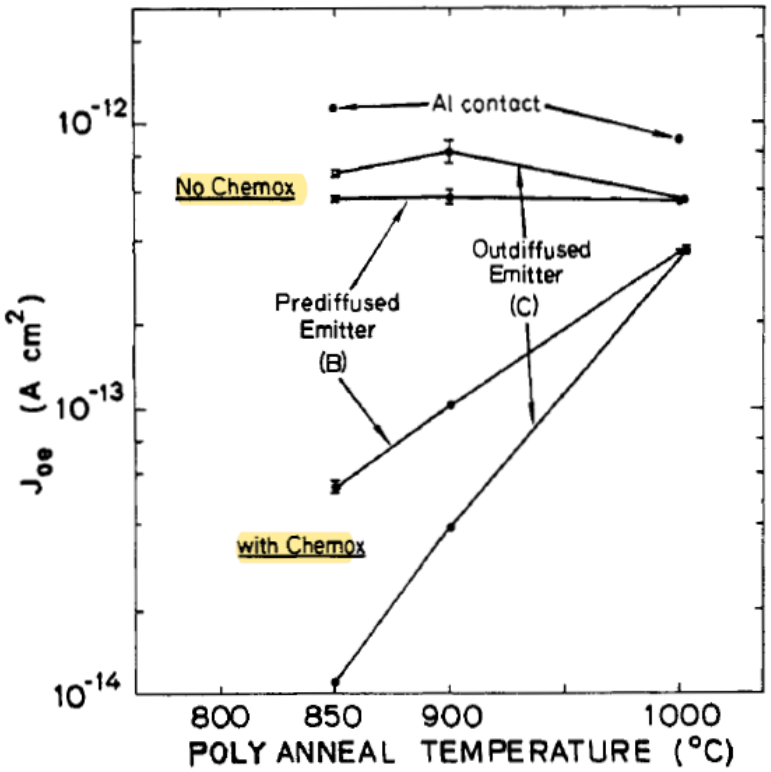


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

And Borden also disclosed in the context of solar cells that the tunnel oxide "prevents epitaxial growth," allowing for "optimum band structure" and "provides a layer to protect the surface from plasma damage." EX1009, Abstract. These benefits apply to both amorphous silicon and polysilicon. EX1003, ¶101; *see also* EX1014 (Foglietti), ¶¶8-9,28,46 (discussing beneficial effects of an interfacial oxide layer).

B. Reasonable Expectation of Success

The Skilled Artisan would have considered the Froitzheim/Gan combination to be merely an arrangement of old elements (and their corresponding fabrication steps) with each performing the same function it had been known to perform (the emitter of Froitzheim continuing to act as an emitter, but modified to be of a polysilicon material with an interfacial oxide layer in between it and the substrate) and yielding no more than what one would expect from such an arrangement (a solar cell with improved performance). EX1003, ¶102.

Specifically, before introducing the boron dopant by diffusion at the rear side of the substrate (for example, as described in ¶40-41 of Froitzheim), the Skilled Artisan would perform Gan's steps of growing a thin thermal oxide to form the interfacial layer followed by polysilicon deposition to form the polysilicon on the oxide layer on the back side of the wafer, after which the polysilicon would be

doped instead of the substrate to form the polysilicon emitter. EX1003, ¶103; EX1007, 246.

Combining Froitzheim/Gan as described here would have been well within the level of ordinary skill in the art. EX1003, ¶104. It would not have resulted in any unpredictable results and could have been readily accomplished without undue experimentation and with a reasonable expectation of success. *Id*. The combination would simply have been the combination of well-known prior art steps in solar cell fabrication to yield predictable results. *Id*. Likewise, substituting Froitzheim's emitter in the substrate with a polysilicon emitter and oxide layer deposited on the substrate would be a simple substitution of one known element and corresponding fabrication steps for another to obtain predictable results. EX1003, ¶105. It would further constitute use of a known technique (depositing polysilicon emitters with an oxide layer) to improve similar devices (Froitzheim's solar cell) in the same way. *Id*. It is nothing more than applying a known technique to a known device ready for improvement to yield predictable results. *Id*.

C. Froitzheim and Gan Disclosed All Claimed Steps

1. Claim 9

a) [9.a] Preamble

To the extent the preamble is limiting, Froitzheim and Gan both disclosed "*method[s] of fabricating a solar cell,*" as shown by the remaining elements. *E.g.*, EX1006, Abstract, Fig. 1; EX1003, ¶106.

b) [9.b] Back surface polysilicon

Claim 9 first recites: "*forming a layer of polysilicon over a back surface of a silicon substrate*." In the Froitzheim/Gan combination, the backside diffused p-type emitter of Froitzheim is replaced with a polysilicon emitter, as taught by Gan. EX1003, ¶107. Gan explicitly suggested that "the cell performance can be improved if the diffused-emitter is replaced with the polysilicon emitter." EX1007, 245. Thus, the step in Gan of forming the polysilicon layer, as described in §VIII.B above, is inserted before the step of boron diffusion at the backside in Froitzheim, as seen in the process steps taught by Gan. EX1003, ¶107.

Specifically, Gan described first forming an oxide layer in steps 1 and 3, followed by depositing a polysilicon layer in step 4 (shown below)—steps which the Skilled Artisan would have integrated into Froitzheim's fabrication process based on the benefits of polysilicon emitters taught by Gan and discussed in §IX.A. EX1003, ¶108.

1. Field oxidation (2000 Å)*.
2. Polysilicon-substrate contact opening*.
3. Thin thermal oxide growth at 800 °C*. (10-minute oxygen flow)
4. Polysilicon deposition (6000 Å) and first-step anneal (1050 °C)*.

EX1007, 246.[3] Thus, the Froitzheim/Gan combination disclosed step 9.b.

c) [9.c]-[9.d] First dopant source and diffusion

Claim 9 next recites: "*forming a first dopant source layer over the layer of polysilicon*" and "*diffusing dopants from the first dopant source layer to the layer of polysilicon to form a backside junction with the silicon substrate*." In the Froitzheim/Gan combination, the replaced polysilicon layer would be doped, as taught by Froitzheim and Gan, by first forming a diffusion source layer and diffusing the dopant from that layer into the polysilicon layer, as shown either in steps 9 and 10 below of Gan or described in ¶¶40-41 of Froitzheim.

[3] To the extent it is argued any unwanted oxide or diffusion source would be formed by any process step for any element, the Skilled Artisan would have readily known that it could easily be selectively removed by an etching step such as the hydrofluoric acid (HF) step of Froitzheim. EX1003, ¶109; EX1006, ¶¶44-45.

1. Field oxidation (2000 Å)*.
2. Polysilicon-substrate contact opening*.
3. Thin thermal oxide growth at 800 °C*. (10-minute oxygen flow)
4. Polysilicon deposition (6000 Å) and first-step anneal (1050 °C)*.
5. First-step anneal *.
6. Polysilicon finger definition.
7. Undoped glass deposition (2000 Å).
8. Metal-polysilicon and metal-substrate contact opening.
9. Doped glass deposition on both sides of the wafer*.
10. Drive-in; 900-1000 °C*.
11. Doped glass stripping and Al-1% Si alloy deposition.
12. Metal finger definition.

EX1007, 246. Specifically, the Skilled Artisan would understand that the "doped glass deposition" step in Gan deposits a "*first dopant source layer*" on the backside polysilicon and the "drive in" step would diffuse the dopant from the "doped glass" layer into the polysilicon layer at high temperature in step 10. EX1003, ¶110. It was well known that the term dopant "drive in" is synonymous with dopant diffusion in solar cell manufacturing. *Id*. citing (EX1019 (Luque)[4] at 265). The '053 Patent specification similarly uses "drive-in" to describe the dopant diffusion step. EX1001, 4:60-66.

[4] EX1032 is an authentic copy of Luque, which was publicly available by August 7, 2003 and was in any event publicly available before February 20, 2007, and thus is prior art pursuant to §§102(a)-(b). EX1032, ¶¶6, 66-72.

The Skilled Artisan would have been motivated to use this doping process to obtain the benefits of a polysilicon emitter and oxide layer taught by Gan (*see* §IX.A), and would have had a reasonable expectation of success that applying the proven technique of Gan would work with Froitzheim. §IX.B; EX1003, ¶111. Gan's diffusion step is compatible with Froitzheim diffusion step because they both use similar diffusion methods. *Id*. For example, Froitzheim disclosed that its p-type emitter is doped "by a process which introduces dopant, preferably boron, ***only by diffusion into the rear surface of the body layer***. Several processes for boron diffusion are known in the art, including diffusion from the gas phase or from liquid and ***solid phases applied to the surface*** [*i.e.*, *doped glass layer of Gan*]." EX1006, ¶40; EX1003, ¶111.

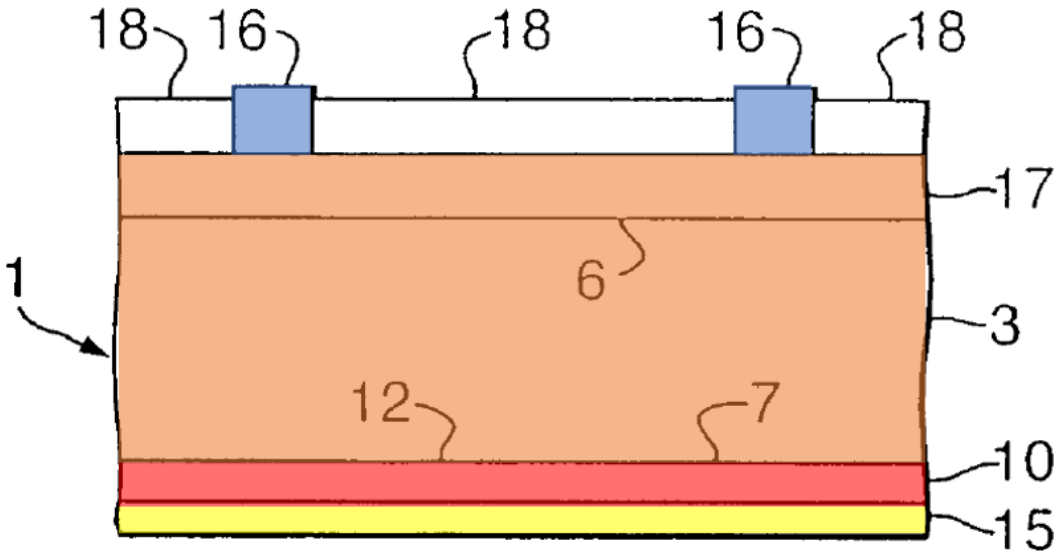
Alternatively, In Froitzheim's preferred process, "a diffusion source layer [*i.e.*, *a first dopant source layer*] that contains boron as a dopant is applied, e.g. spun, only onto the back of the n-doped silicon wafer. The diffusion source layer is one that contains boron and out of which the boron is thermally driven." EX1006, ¶41; EX1003, ¶112.

Thus, either way, in the Froitzheim/Gan combination, this two-step boron/p-type dopant diffusion process would similarly be performed on the back side, as taught by Froitzheim, after deposition of the polysilicon layer as taught by Gan, to form a *backside junction* with the N-type substrate. EX1003, ¶113. And instead of

diffusing into the substrate, the boron/p-type dopant diffuses into the polysilicon layer in the Froitzheim solar cell, as modified by Gan, in the same way as recited in the claim. *Id*. Thus, the Froitzheim/Gan combination disclosed steps 9.c and 9.d.

d) [9.e] Diffusing front of substrate

Claim 9 next recites: "*diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation*." Froitzheim disclosed this step by forming a "front surface field," or "n+ doped region" at the front side of the substrate. EX1006, FIG. 1 (element 17), ¶15. In Froitzheim, "[d]uring normal operation of the solar cell 1 the front side 6 faces the sun and light is received through the area of the front surface that is not covered by the front contact 16." EX1006, Figure 1, ¶32.

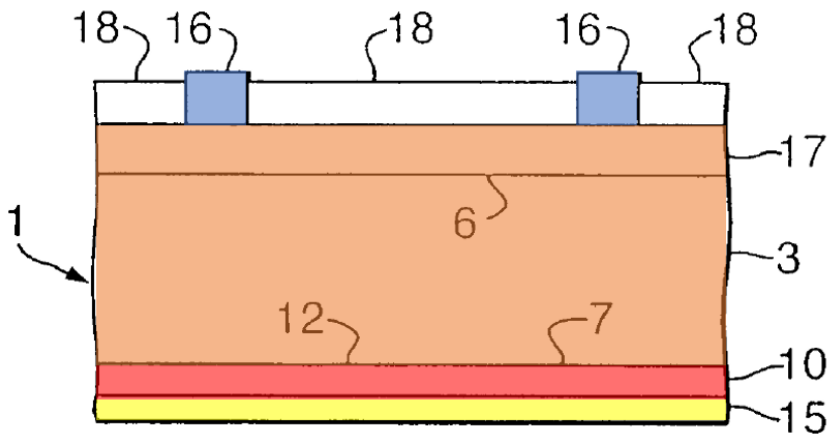


To form the "front surface field" or "n+ doped region," Froitzheim disclosed diffusing phosphorus into a front surface of the silicon substrate. EX1003, ¶115. Froitzheim disclosed: "after the p-doped region has been formed the oxide layer can be removed from the front surface, e.g., using HF, and optionally also the diffusion source layer and oxide layer from the rear surface, ***followed by a diffusion of Phosphorous from the gas phase to form a front side n+ layer***." EX1006, ¶44. Thus, Froitzheim disclosed step 9.e. EX1003, ¶114-115.

e) [9.f] Metal front contact

Claim 9 next recites: "*forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate*." Froitzheim disclosed this step. EX1003, ¶¶116-120.

Froitzheim taught: "At the front side 6, ***screen-printed front side contacts 16 are provided in electrical connection with the n-type silicon body layer***." EX1006, ¶28. "Front and rear side contacts are preferably screen-printed in an industrial production process, and contacting done at elevated temperatures." EX1006, ¶48. The screen-printing of the front side contacts 16 highlighted blue in Figure 1 below satisfy step 9.f. EX1003, ¶117.



Dr. Banerjee explains that it was well known in the art that screen-printed contacts are made from silver paste, which forms metal contacts. EX1003, ¶118 citing EX1019, 275, 277 (Luque's Handbook of Photovoltaic Science and Engineering); EX1011, 7:10-35 (silver paste for front screen printing). Froitzheim likewise disclosed that its screen printed contacts contain silver and thus would be metal contacts. EX1003, ¶119; EX1006, ¶¶49, 60. And silver was the conventional conductive material to use in a front screen printing paste, as also disclosed by Meier. EX1003, ¶118; EX1011 (Meier) at 7:10-35 ("FIG. 3D shows the structure resulting after depositing metal contacts and firing through the optional anti-reflective coating. By way of example, a silver layer is screen-printed onto the n+ layer 216, covering about 7% of the front surface in a grid pattern.")

Thus, the combination of Froitzheim/Gan disclosed all steps in Claim 9 and rendered its method obvious.

To the extent that Maxeon argues that Froitzheim does not disclose metal contacts, which would be incorrect, the Skilled Artisan would find it obvious that Froitzheim would use silver paste for screen printing the front contacts, and thus form metal contacts on the front, in further view of Meier. EX1003, ¶120.

2. Claim 10 – P-type dopants

Claim 10 depends from claim 9 and recites: "*wherein the first dopant source layer comprises P-type dopants*." Froitzheim disclosed this element. For example, Froitzheim disclosed forming a p-type emitter using a boron diffusion source layer, and boron is a *P-type dopant*. EX1006, ¶¶40-41; EX1003, ¶122.

3. Claim 11 – borosilicate glass

Claim 11 depends from claim 9 and recites: "*the first dopant source layer comprises borosilicate glass.*" Froitzheim also disclosed this element because it was well known that the "spun" on boron source layer in Froitzheim would form borosilicate glass during the process. EX1003, ¶123. Specifically, Froitzheim disclosed doping the emitter, preferably, by spin coating a "diffusion source layer that contains boron as a dopant" and thereafter "thermally driv[ing] in" the boron. EX1006, ¶41. Such a spin-on boron-containing diffusion source layer was well known to form "borosilicate glass" upon heating. EX1003, ¶123. For example, a publication by Nolan in 2000 described the "spectroscopic investigation" of borosilicate glass as "dopant source for proximity rapid thermal diffusion."

EX1030, 3100. Nolan explained that the composition and structure of a "borosilicate gel" that is spun on the silicon wafer changes to "borosilicate glass" upon heating. *Id.*; EX1003, ¶123.

Moreover, Gan also disclosed this element because its dopant source layer is "doped glass," which when used with a boron dopant would have been "borosilicate glass." EX1003, ¶128; EX1007, 246; EX1042, 379.

4. Claim 14

Claim 14 depends from claim 9 and recites: "*texturing the front surface of the silicon substrate"* and *"forming an antireflective layer over the textured front surface of the silicon substrate*."

f) [14.a] Texturing

Froitzheim disclosed texturing of the front surface. EX1003, ¶126. It stated: "***If desired a short, alkaline crystal-oriented etching can be used to texture the surface*** in order to improve the geometry of incidence of light in order to prevent reflection." EX1006, ¶39. As Dr. Banerjee explains, the Skilled Artisan would understand that solar cells receive most of the incident light on the front surface. EX1003, ¶126. And texturing of the front surface would have been desirable because it prevents reflection of the light away from the cell and deflects the light into the cell body. *Id*. (citing EX1019 (Luque), 269).

g) [14.b] Antireflective layer

The 053 Patent discloses silicon nitride as an antireflective layer. EX1001, 2:57-63. Froitzheim likewise disclosed that "SiN [silicon nitride] was used in all cases as antireflection as well as surface passivation coating for n- and p-type silicon." EX1006, ¶60. Froitzheim also disclosed using silicon nitride for the front surface passivation. *Id*., ¶19, 30-31. And it was well known even before 2008 that silicon nitride functions both as an antireflective and a passivation layer at the same time. EX1003, ¶133 (citing EX1019 (Luque), 274 and EX1022 (Duerinckx), 232).

Froitzheim also disclosed that the silicon nitride anti-reflection coating is applied after the step of texturing and front dopant diffusion in the manufacturing process. EX1006, ¶¶38-39, 50. Thus, the antireflective layer would be formed over the *textured front surface* of the substrate because it is applied after texturing and diffusion of the front dopants. EX1003, ¶128.

5. Claim 16

Independent claim 16 recites the same method steps as claim 9, except that it additionally recites a step of "*forming an oxide layer over a back surface of a silicon substrate,* before the polysilicon layer formation such that the polysilicon layer is formed on the oxide layer. The combination of Froitzheim and Gan disclosed all steps in Claim 16. EX1003, ¶¶131-135.

a) [16.a] Preamble

To the extent the preamble is limiting, Froitzheim and Gan both disclosed *methods of fabricating a solar cell*. *See* [9.a] and remaining elements.

b) [16.b] Oxide layer and [16.c] Polysilicon

Claim 16 recites: "*forming an oxide layer over a back surface of a silicon substrate*" and "*forming a layer of polysilicon over the oxide layer*."

In replacing the diffused emitter of Froitzheim with the polysilicon emitter of Gan, Gan likewise taught to first form an oxide layer before forming the polysilicon layer on the oxide layer, as shown in steps 1 and 3-4 of Gan. EX1003, ¶134.

> 1. Field oxidation (2000 Å)*.
> 2. Polysilicon-substrate contact opening*.
> 3. Thin thermal oxide growth at 800 °C*. (10-minute oxygen flow)
> 4. Polysilicon deposition (6000 Å) and first-step anneal (1050 °C)*.

EX1007, 246. As discussed in §IX.A above, the Skilled Artisan would have been motivated to replace Froitzheim's backside, diffused emitter layer with a polysilicon layer to improve the solar cell. EX1003, ¶134. And by doing so, the Skilled Artisan would also have been motivated to form an oxide layer in between the polysilicon and substrate, as taught by Gan because of the beneficial effects of having the oxide layer in between, as discussed in §IX.A. *Id.*

c) [16.d] Diffusing backside junction, [16.e] Diffusing front, and [16.f] Metal contact

Froitzheim/Gan also disclosed [16.d], [16.e], and [16.f] for substantially similar reasons as steps [9.d], [9.e], and [9.f] and discussed in §§IX.C.1.c) to IX.C.1.e). EX1003, ¶135. Except for omitting the element "first dopant source layer," the process steps of [16.d], [16.e], and [16.f] are identical to the process steps of [9.d], [9.e], and [9.f].

6. Claim 17 – First dopant source

Claim 17 depends from claim 16 and additionally recites substantially the same element as [9.c] and [9.d] of claim 9, referring to forming and diffusing from a first dopant source layer. Froitzheim/Gan would have rendered claim 17 obvious for similar reasons as discussed for steps [9.c]-[9.d] of claim 9 in §IX.C.1.c) above.

7. Claims 19 and 20 – Texturing and Antireflective Layer

Claims 19 and 20 depend from claim 16 and additionally recite substantially the same elements as claim 14 referring to texturing and an antireflective layer. Froitzheim/Gan would have rendered claims 19-20 obvious for similar reasons as discussed for claim 14. *See* §§IX.C.4.

X. CLAIMS 11-13, 15 AND 18 ARE UNPATENTABLE OVER FROITZHEIM AND GAN IN FURTHER VIEW OF HARTITI OR SIVOTHTHAMAN

1. Claim 12 – Second dopant source layer

Claim 12 depends from claim 9 and requires a "*second dopant source layer*" for the dopant diffusion of the front surface. It recites: "*diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate*." In one embodiment, the 053 Patent disclosed that this "second dopant source layer" comprises "silicon dioxide doped with phosphorus," which is phosphosilicate glass (PSG). EX1001, 4:51-52; EX1003, ¶138.

As discussed in §IX above, Froitzheim/Gan rendered the method of claim 9 obvious. Claim 12 would have been obvious over Froitzheim and Gan in further view of EX1012, Hartiti et al., "Low Temperature Formation of Emitter and BSF by Rapid Thermal Co-Diffusion of P, Al, or B," IEEE 1st Word Conference on PV Energy, (1994) p.1519 ("Hartiti") ***or*** EX1013, Sivoththaman et al, "Rapid Thermal Processing of Conventionally and Electromagnetically Cast 100 cm^2 Multicrystalline Silicon," Conference Record of the Twenty Fifth IEEE Photovoltaic Specialists Conference - 1996, Washington, DC, USA, 1996, pp. 621-624 ("Sivoththaman"). EX1003, ¶139.

Both Hartiti and Sivoththaman taught diffusing phosphorus (n-type) dopants into the front side of the solar cell's substrate from "phosphorus doped glass films deposited by spin-on technique or AP-CVD oxides" (Hartiti, EX1012, 1519), which is otherwise known as "phosphosilicate glass PSG (P_2O_5:SiO_2)." EX1013, 621; EX1003, ¶140. "Glass" is made up of silicon dioxide (SiO_2). EX1003, ¶140. Thus, it was well known in the art that "phosphorus doped glass films" are silicon dioxide doped with phosphorus, as evident by the formula P_2O_5:SiO_2 disclosed by Sivoththaman. *Id*. Notably, dependent claim 13 defines the second dopant source layer to comprise "*phosphorus doped silicon dioxide.*" Thus, depositing this PSG layer, as taught by Hartiti or Sivoththaman, meets the step of "*forming a second dopant source layer over the silicon substrate*," and the thermal drive-in step, as also taught by Hartiti and Sivoththaman, for the phosphorus diffusion from the PSG meets the step of "*diffusing dopants from the second dopant source layer into the silicon substrate*," in claim 12. EX1003, ¶140

a. Hartiti (EX1012)

Hartiti is prior art under pre-AIA 35 U.S.C. §102(a) and (b) because it was presented in 1994 at a conference (EX1012, xiv) and published by June 29, 1995 and no later than August 6, 2002. EX1032, ¶¶6, 80-86. As of June 29, 1995, it was indexed, catalogued and made available by the National Renewable Energy Laboratory Library. EX1032, ¶¶82-83. It was also available for download

electronically from IEEE Xplore by August 6, 2002, and in any event was publicly available before February 20, 2007. EX1032, ¶81; EX1053. It was widely distributed and was also known and cited by others before 2003, including in an International Search Report for a PCT Application, further confirming its public dissemination before February 20, 2007. EX1032, ¶84-¶85; EX1054 (reference 6); EX1059; EX1055, p. 14. Exhibit 1012 is an authentic copy of Hartiti that was published before February 20, 2007. EX1032, ¶¶6, 52-58. Thus, it is prior art under 35 U.S.C. §102(a) and (b).

As Dr. Banerjee explains, Hartiti disclosed the "co-diffusion of two dopant elements in a single rapid thermal cycle at low temperature in order to form [front] emitter and BSF [back surface field] simultaneously" in a solar cell. EX1012, Abstract; EX1003, ¶142. Hartiti disclosed that "rapid thermal processing (RTP) is now emerging as a promising simplified process for manufacturing of terrestrial solar cells in a continuous way." EX1012, Abstract. And Hartiti presented experimental results showing the benefits of simultaneously diffusing the front and back dopants of the solar cell, stating:

> We have, in particular, found that the diffusion kinetics of dopant elements are enhanced during rapid thermal co-diffusion of P, AI or B and lead to the optimal dopant activity and profile for high efficiency silicon solar cells at low temperature. Additionally, the gettering effect induced by the co-diffusion of P and AI is more efficient than can be achieved by a single diffusion of these two elements.

EX1012, 1519. As reported by Hartiti, enhancement of the dopant diffusion kinetics was observed in co-diffusion of phosphorus and boron regardless of whether the dopant sources were "spin-on glasses" (as shown in Fig. 2) or "AP-CVD silicate sources." EX1012, 1520. APCVD refers to "atmospheric pressure chemical vapor deposition." EX1003, ¶142; EX1001, 4:23-25.

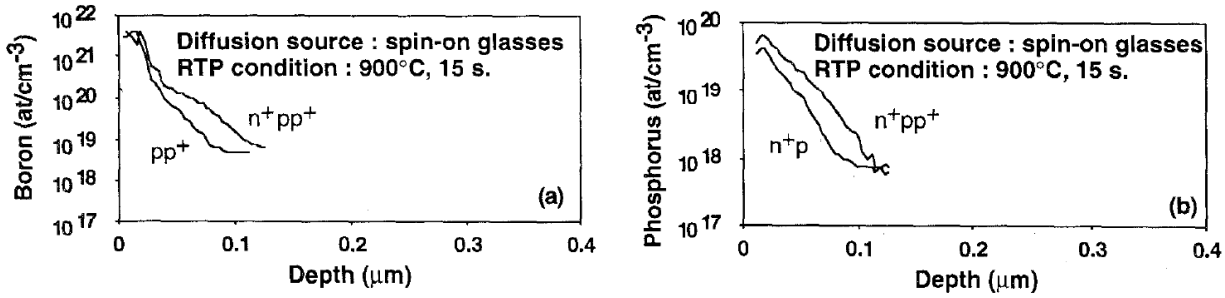


Fig. 2. Mutual enhancement in diffusion for (a) boron and (b) phosphorus.

The enhancement of the diffusion kinetics allows "reduc[tion] of the processing temperature," which saves energy and reduces costs of manufacturing. EX1012, 1522; EX1003, ¶142.

b. Sivoththaman (EX1013)

Sivoththaman is prior art under pre-AIA 35 U.S.C. §102(a) and (b) because it was presented in 1994 at a conference (EX1013, face, v) and published by at least 1997 and no later than August 6, 2002, when it was made available electronically for download from IEEE Xplore, and in any event was publicly available before February 20, 2007. EX1032, ¶¶6, 59-65; EX1049. It was widely distributed and has also been known and cited by others in the field long before February 20, 2007, further confirming its public dissemination before the critical

date. EX1032, ¶65; EX1050; EX1051; EX1052; EX1056; EX1057; EX1058. Exhibit 1013 is an authentic copy of Sivoththaman that was published before February 20, 2007. EX1032, ¶¶6, 59-65. Thus, it is prior art under 35 U.S.C. §102(a) and (b).

Dr. Banerjee explains that like Hartiti, Sivoththaman disclosed rapid thermal co-diffusion of phosphorus and boron into the front and back surfaces, respectively, of solar cell substrates. EX1003, ¶144. Specifically, for the front, "APCVD deposited PSG was used as diffusion source." EX1013, 622. "PSG" refers to "phosphosilicate glass" (P_2O_5:SiO_2). EX1013, 621; EX1003, ¶144. For the back, "APCVD borosilicate glass (BSG)" was used as the diffusion source. EX1013, 622. The front and back diffusion were performed in a single "rapid thermal diffusion" ("RTD") step in N2 ambient at a temperature range of 875-950°C. EX1013, 621; EX1003, ¶144.

c. Motivation to Combine

As Dr. Banerjee explains, while Froitzheim's front diffusion process used phosphorus gas as the diffusion source, the Skilled Artisan would have been motivated to replace the phosphorus gas diffusion source with a spin-on or APCVD deposited phosphosilicate glass (PSG), as taught by Hartiti or Sivoththaman. EX1003, ¶145. Doing so would allow the co-diffusion of the phosphorus and boron at the front and back sides of the solar cell in a single drive-

in diffusion step, as disclosed by Hartiti and Sivoththaman. *Id*. Co-diffusion in a single step would reduce the number of high temperature processing steps, as disclosed by Hartiti, resulting in energy savings and cost reduction and simplification in the manufacturing process. *Id*.; EX1012, 1522. See also, EX1003, ¶¶145-146.

d. Reasonable Expectation of Success

The spin-on or APCVD PSG films, as taught by Hartiti or Sivoththaman would be a "*a second dopant source layer*" deposited over the front of the substrate, as recited in claim 12. EX1003, ¶147. The Skilled Artisan would have reasonably expected that Froitzheim's phosphorus gas source can be substituted with the PSG film and still result in a working solar cell. *Id*.

For example, Froitzheim's preferred method for the backside boron diffusion was the spin-on technique, which is also the technique used by Hartiti to deposit both the front and back dopants. EX1003, ¶147. Froitzheim does not require that the phosphorus be diffused from a gas source, or that the boron be diffused only from a spun-on source. *Id*. Froitzheim disclosed that diffusion can be performed as was "known in the art, including diffusion from the gas phase, or from liquid and *solid phases applied to the surface*." EX1006, ¶40 (emphasis added).

As Dr. Banerjee explains, the Skilled Artisan would have considered the implementation of Hartiti or Sivoththaman's spin-on or APCVD deposited PSG with the Froitzheim/Gan combination of solar cell to be merely an arrangement of old method steps with each performing the same function it had been known to perform as a diffusion source layer for phosphorus and yielding no more than what one would expect from such an arrangement—a configuration that allows for co-diffusion of the front and back dopants. EX1003, ¶148.

Combining Froitzheim/Gan with Hartiti or Sivoththaman as described here would have been well within the level of ordinary skill in the art, would not have resulted in any unpredictable results and could have been readily accomplished without undue experimentation and with a reasonable expectation of success. EX1003, ¶149. The combination would simply have been the combination of well-known prior art steps in solar cell fabrication to yield predictable results. *Id*. It would further constitute use of a known technique (depositing PSG as a diffusion source layer) to improve the process of manufacturing a solar cell in the same way. *Id*.

2. Claim 13 – Phosphorus

Claim 13 depends from claim 12 and recites: "*the second dopant source layer comprises phosphorus doped silicon dioxide*." As discussed in §X.1 for claim 12, the deposited PSG layer, as taught by Hartiti or Sivoththaman, as the

dopant source layer constitutes a "*phosphorus doped silicon dioxide*" as evident by the formula P_2O_5:SiO_2 disclosed by Sivoththaman, which is the formula for phosphorus doped silicon dioxide. EX1003, ¶¶140-144, 150. Thus, claim 13 would have been obvious for the same reasons as discussed for claim 12.

3. Claim 18 – Second dopant source

Claim 18 depends from claim 16 and recites the same process steps required by claim 12 of "*diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate*."

Froitzheim/Gan would have rendered claim 16 obvious, as discussed in §IX.C.5 above. Because Claim 18 recites the same steps as Claim 12, it would have been obvious over Froitzheim and Gan in further view of Hartiti or Sivoththaman for the same reasons discussed for claim 12. *See* §X.1 above.

4. Claim 11 – borosilicate glass

Claim 11 depends from claim 9 and recites: "*the first dopant source layer comprises borosilicate glass*." To the extent that Maxeon argues that Claim 11 would not have been obvious by the combination of Froitzheim and Gan alone, Claim 11 would also have been obvious over Froitzheim and Gan in further view of Hartiti or Sivoththaman. Hartiti and Sivoththaman both taught the use of borosilicate glass (BSG) as the dopant source layer for the backside of the solar

cell. EX1012, 1520 (The same enhancement of diffusion kinetics "can also be observed when the co-diffusion of the P[hosphorus] and B[oron] are performed from AP-CVD ***silicate*** sources."); EX1013, 622 ("For the BSF, … APCVD ***borosilicate glass (BSG)*** … was used as RT-diffusion source[]."); EX1003, ¶¶153-156.

Dr. Banerjee explains that the Skilled Artisan would have been motivated to use BSG for the back side diffusion and PSG for the front side diffusion so that they can be co-diffused in a single drive-in step, as taught by Hartiti and Sivoththaman. EX1003, ¶154. Co-diffusion would beneficially result in enhanced diffusion kinetics and reduction in the manufacturing process steps, thereby saving energy and costs of manufacturing. EX1012, 1519; EX1003, ¶154.

The Skilled Artisan would also reasonably expect success in combining Froitzheim/Gan with Hartiti or Sivoththaman because depositing the BSG and PSG of Hartiti and Sivoththaman would constitute the "doped glass deposition" as used in step 9 of Gan. EX1003, ¶155. As Froitzheim also recognized, the diffusion can be any diffusion technique known in the art "including diffusion from the gas phase or from liquid and solid phases applied to the surface." EX1006, 40. And to the extent it is somehow argued that Froitzheim and Hartiti's spin-on BSG is not a *dopant source layer*, the Skilled Artisan would have considered the spin-on BSG

of Froitzheim and Hartiti to be reasonably interchangeable with the AP-CVD deposition of BSG as taught by Hartiti or Sivoththaman. EX1003, ¶155.

5. Claim 15 – In situ

Claim 15 depends from claim 9 and further requires *wherein the diffusion of dopants from the first dopant source layer to the layer of polysilicon and the diffusion of dopants into the front surface of the silicon substrate are performed in situ*. Claim 15 would have been obvious based on Froitzheim and Gan in further view of Hartiti or Sivoththaman. Gan, Hartiti, and Sivoththaman all disclosed a single "in situ" drive-in/diffusion step for the front and back dopants. EX1003, ¶¶156-158.

The 053 Patent explains the term "in-situ" as follows:

> The drive-in step to dope the polysilicon emitter 108 on the backside and to form the N-type doped regions 105 and 106 on the front side may be formed *in-situ, which in the context of the present disclosure means* ***a <u>single</u> manual (i.e., by fabrication personnel) loading of the substrate 101 in a furnace or other single chamber or multi-chamber processing tool.*** In one embodiment, the drive-in step is performed in a diffusion furnace. The preceding sequence of steps leading to the drive-in step allows for in-situ diffusion, which advantageously helps in lowering fabrication cost.

EX1001, 5:9-18. Thus, in the context of the 053 Patent, "in situ" refers to processing that occurs after a single manual loading of the substrate into a furnace or other single chamber or multi-chamber processing tool. EX1003, ¶157. Therefore, in the context of claim 15's diffusion steps, the single, simultaneous

drive-in/diffusion of the front and back dopants would constitute "in situ" steps that satisfy the claim. *Id*.

Dr. Banerjee explains that this "in-situ" step is met by either Hartiti or Sivoththaman because they both disclose the simultaneous, single step co-diffusion of the front and back dopants in a single rapid thermal processing unit, "model FAV4 of Jipelec (Grenoble, France)." EX1003, ¶158 citing EX1012, 1519; EX1013, 621 ("A commercial RTP furnace was used.") The Skilled Artisan would understand that in a co-diffusion technique with a single heating step, as taught by Hartiti or Sivoththaman, the fabrication personnel, after the front PSG and back BSG depositions of the dopants, would perform a single manual loading into the RTP furnace for a combined drive-in/diffusion step. EX1003, ¶158. As Dr. Banerjee explains, the wafer must have undergone a loading into the thermal processing unit, i.e., the commercial RTP furnace, at to undergo the simultaneous drive-in/diffusion. *Id*. And since they were diffused simultaneously, they must be done in the same manual loading. *Id*. The Skilled Artisan would be motivated to perform co-diffusion, as already discussed in §X.1.c above, and would also reasonably expect to succeed, as discussed in §X.1.d above.

XI. CLAIMS 9-11, 14, 16-17, AND 19-20 ARE UNPATENTABLE OVER FROITZHEIM AND KWARK

The combination Froitzheim and Kwark would have rendered Claims 9-11, 14, 16-17, and 19-20 obvious and unpatentable. The combination of Froitzheim

and Kwark is similar to the previous combination of Froitzheim and Gan, except that Kwark, instead of Gan, supplies the elements for forming the polysilicon emitter and the oxide layer in between. EX1003, ¶¶160-178.

A. Motivation to Modify Froitzheim and Kwark

Froitzheim and Kwark are analogous art because each is in the same field of endeavor—solar cell design.[5] EX1003, ¶161; EX1006, Abstract, ¶¶1,9; EX1008, 742. Each is reasonably pertinent to the problems of efficiency and cost-effectiveness of solar cell designs. EX1003, ¶161; EX1006, Abstract, ¶¶1,9; EX1008, 742.

Dr. Banerjee explains that the Skilled Artisan would have been motivated to modify Froitzheim's emitter to be a polysilicon emitter with an oxide layer because Kwark taught and suggested that this modification would be an improvement transferable to solar cells. EX1003, ¶162. Kwark taught that addition of an interfacial chemically grown oxide (chemox) between polysilicon and the substrate "greatly decreases the J_{oe}," which "translates into potential improvements of energy conversion efficiency for solar cells." EX1008, 742, 745. Kwark provided

[5] To the extent it is argued Kwark is directed to a bipolar transistor, a Skilled Artisan would have looked to it when designing solar cells as was commonly done in the art. EX1003, ¶161; EX1020, 363; EX1021, 497; EX1007, 245; EX1016, 597.

data comparing polysilicon emitters with and without the oxide layer, and noted "the large difference when the interfacial oxide is missing." EX1008, 745 Fig. 4.

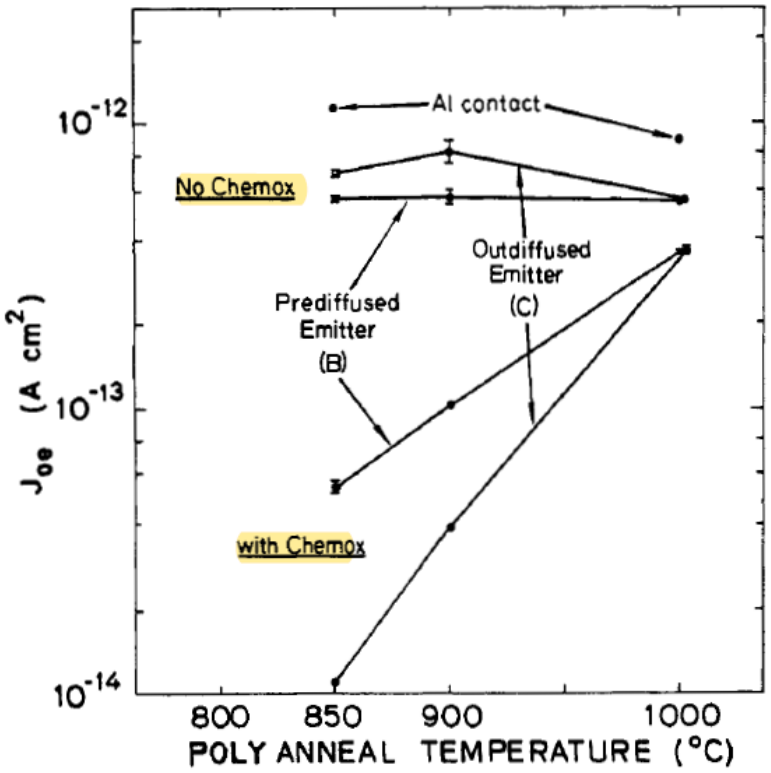


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

The teachings of Froitzheim, Gan, Foglietti, and Borden discussed in §IX.A would similarly have motivated a Skilled Artisan to integrate a polysilicon emitter with interfacial oxide layer in Froitzheim in view of Kwark because of the benefits of polysilicon emitter and interfacial oxide layer. EX1003, ¶167.

B. Reasonable Expectation of Success

The Skilled Artisan would have considered the Froitzheim/Kwark combination to be merely an arrangement of old method steps with each performing the same function it had been known to perform (the emitter of Froitzheim continuing to act as an emitter, but modified to be polysilicon with an interfacial oxide) and yielding no more than what one would expect from such an arrangement (a solar cell with improved performance). EX1003, ¶164.

Combining Froitzheim/Kwark as described here would have been well within the level of ordinary skill in the art, would not have resulted in any unpredictable results and could have been readily accomplished without undue experimentation and with a reasonable expectation of success. EX1003, ¶165. The combination would simply have been the combination of prior art elements according to known methods to yield predictable results. *Id*. Likewise, substituting Froitzheim's in-substrate diffused emitter with a polysilicon emitter and oxide layer would be simple substitution of one known element for another to obtain predictable results. *Id*. It would further constitute use of a known technique (polysilicon emitters with an oxide layer) to improve similar devices (Froitzheim's solar cell) in the same way. *Id*. It would also constitute applying a known technique to a known device ready for improvement to yield predictable results. *Id*.

C. Froitzheim and Kwark Disclosed All Elements

1. Claim 9

a) [9.a] Preamble

Froitzheim discloses *a method of fabricating a solar cell* as shown by the remaining elements. *E.g.*, EX1006, Abstract, Fig. 1; EX1003, ¶170.

b) [9.b] Back surface polysilicon

Claim 9 first recites: "*forming a layer of polysilicon over a back surface of a silicon substrat*e." In the Froitzheim/Kwark combination, the backside diffused p-type emitter of Froitzheim is replaced with a polysilicon emitter, as taught by Kwark. EX1003, ¶167. Thus, the step in Kwark of forming the polysilicon layer by deposition using a "APCVD reactor" is inserted as a step to form the backside polysilicon layer before the step of boron diffusion in Froitzheim. EX1008 742-743; EX1003, ¶171.

c) [9.c]-[9.d] First dopant source and diffusion

As discussed in §IX.C.1.c), Froitzheim disclosed steps [9.c] and [9.d]. Thus, the Froitzheim/Kwark combination meet these two steps.

d) [9.e] Diffusing front of substrate

As discussed in §IX.C.1.d), Froitzheim disclosed step [9.e]. Thus the Froitzheim/Kwark combination would meet this step.

e) [9.f] Metal front contact

As discussed in §IX.C.1.e), Froitzheim disclosed [9.f]. Thus the Froitzheim/Kwark combination would meet this step.

2. Claim 10 – P-type dopants

As discussed in §IX.C.2, Froitzheim disclosed *p-type dopants* for the "*first dopant source layer*," as recited in claim 10. Thus, the Froitzheim/Kwark combination would have rendered claim 10 obvious.

2. Claim 14

As discussed in §§IX.C.4.a)-IX.C.4.b), Froitzheim disclosed "*texturing the front surface of the silicon substrate, and forming an antireflective layer over the textured front surface*." Thus, the Froitzheim/Kwark would have rendered claim 14 obvious.

3. Claim 16

a) [16.a] Preamble

To the extent the preamble is limiting, Froitzheim discloses *a method of fabricating a solar cell*. *See* [9.a] and remaining elements.

b) [16.b] Oxide layer and [16.c] polysilicon layer

As described in §VIII.C, Kwark taught to form a "chemically grown oxide (chemox) layer" before the APCVD deposition of the polysilicon layer, such that the oxide layer is between the polysilicon layer and the substrate. EX1008, 743; EX1003, ¶174. This oxide layer beneficially "decreases the Joe" which translates

into improvements for solar cell efficiency. *Id.* Given this benefit, the Skilled Artisan would have modified Froitzheim's solar cell and replaced its diffused backside emitter structure with an oxide layer followed by the deposited polysilicon layer, as taught by Kwark. *Id*.

Thus, the combination of Froitzheim/Kwark disclosed first *forming an oxide layer over the back surface of a silicon substrate*" and "*forming a layer of polysilicon over the oxide layer*." EX1003, ¶175; *see also* [9.b].

c) [16.d] Diffusing backside junction, [16.e] Diffusing front, and [16.f] Metal contact

Froitzheim/Kwark also disclosed [16.d], [16.e], and [16.f] for substantially similar reasons as steps [9.d], [9.e], and [9.f] and discussed in §§IX.C.1.c) to IX.C.1.e). EX1003, ¶176.

4. Claim 17 – First dopant source

Froitzheim/Kwark rendered the method of claim 16 obvious as set forth above. Claim 17's further requirements are substantially similar to [9.c]-[9.d], and claim 17 was obvious for similar reasons.

5. Claims 19 and 20 – Texturing and anti-reflective layer

Froitzheim/Kwark rendered the method of claim 16 obvious as set forth above. Claim 19, which requires *texturing the front surface of the silicon substrate*, was obvious for similar reasons to claim 14 that has the same requirement. Claim 20, which requires *forming an antireflective layer over the*

textured front surface of the silicon substrate, was obvious for similar reasons to claim 14 that has the same requirement.

XII. CLAIMS 11-13, 15 AND 18 ARE UNPATENTABLE OVER FROITZHEIM AND KWARK IN FURTHER VIEW OF HARTITI OR SIVOTHTHAMAN

1. Claim 12 – Second dopant source layer

Claim 12 depends from claim 9 and requires a "*second dopant source layer*" for the dopant diffusion of the front surface. It recites: "*diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate*."

Froitzheim and Kwark would have rendered obvious Claim 9, as discussed in §XI.C.1 above. Although Froitzheim and Kwark do not disclose the additional limitation of Claim 12, Hartiti and Sivoththaman do, as discussed in §X.1 above. As Dr. Banerjee explains, the Skilled Artisan would be motivated to replace the phosphorus gas diffusion source of Froitzheim with a spin-on or APCVD deposited phosphosilicate glass (PSG), as taught by Hartiti or Sivoththaman. EX1003, ¶180. Doing so would allow the co-diffusion of the phosphorus and boron at the front and back sides of the solar cell in a single drive-in diffusion step, as disclosed by Hartiti and Sivoththaman. *Id*. Co-diffusion would enhance the diffusion kinetics and reduce the number of high temperature processing steps, as disclosed by

Hartiti, which results in energy savings and cost reduction in the manufacturing process. EX1012, 1522; EX1003, ¶180.

Thus, Claim 12 would have been rendered obvious by Froitzheim and Kwark in further view Hartiti and Sivoththaman for substantially similar reasons as discussed in §X.1 above.

2. Claim 13 – Phosphorus

Claim 13 would have been obvious for the same reasons as discussed in §X.2 above, with Hartiti and Sivoththaman disclosing the additional limitation of a "*phosphorus-doped silicon oxide layer*" as the "*second dopant source layer*."

3. Claim 18 – Second dopant source

Claim 18 would have been obvious for the same reasons as discussed in §X.3 above, with Hartiti and Sivoththaman disclosing the additional limitation of a "*second dopant source layer*."

4. Claim 11 – borosilicate glass

Claim 11 would have been obvious for the same reasons as discussed in §X.4 above, with Hartiti and Sivoththaman disclosing the additional limitation of a "*borosilicate glass*."

5. Claim 15 – in situ co-diffusion

Claim 15 would have been obvious for the same reasons as discussed in §X.5 above, with Hartiti and Sivoththaman disclosing the additional limitation of a performing the diffusion of the front and back sides "in situ."

XIII. OBJECTIVE FACTORS SUPPORT OBVIOUSNESS

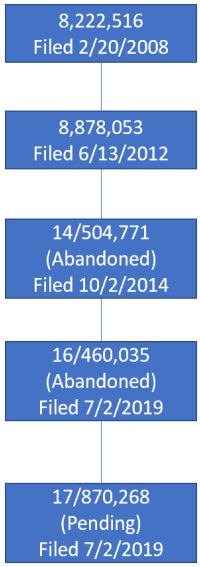
There is no commercial success attributable to the 053 Patent claims. EX1003, ¶¶186-199. Neither Maxeon nor its predecessor SunPower practiced the 053 Patent because their commercial products are all back-contact solar cells, rather than front contact solar cells. *Id*. Back contact solar cells have both first and second metal contacts on the backside, unlike the claimed invention of the 053 Patent that requires forming front metal contacts. *Id.,* ¶¶188-189. Moreover, although Maxeon has brought suit alleging that the 053 Patent covers the methods of making a TOPCon solar cell, the TOPCon solar cell does not practice the 053 Patent because it does not form or include a backside junction with the substrate. EX1003, ¶¶191-199. Rather, the backside polysilicon layer of the TOPCon solar cell has the same polarity as the substrate, and thus forms instead a back surface field, just like the prior art Lindolm and Sylvestre, that were distinguished by the Applicant during prosecution of the 053 Patent and its continuation application. EX1003, ¶¶193-198.

There is also no unexpected result in replacing the backside diffused emitter in a back junction solar cell like Froitzheim with a polysilicon emitter having an interfacial oxide layer in between, as taught by Gan and Kwark. EX1003, ¶200. The Skilled Artisan would have expected to reap benefits from such modification such as higher solar cell efficiencies and lower recombination, as seen from the

teachings of Gan and Kwark. *Id*. And including an oxide layer between the polysilicon layer and the substrate was well-known to confer expected benefits as well. In fact, making such a modification to Froitzheim was simply following the conventional wisdom. *Id*.

Furthermore, there was no unexpected result from using spin-on or APCVD silicate glass films as dopant source layers for diffusing the front and back of the solar cells. EX1003, ¶201. Neither was there any unexpected result in simultaneously co-diffusing "in situ" the front and back dopants. *Id*. Performing such steps was nothing more than following the conventional wisdom as taught for example by Hartiti and Sivoththaman. *Id.* Thus, the objective indicia demonstrate that the 053 Patent claims were nothing but obvious. *Id*.

XIV. PTAB'S UNPATENTABILITY DECISIONS IN TWO CONTINUATION APPLICATIONS SUPPORT A FINDING OF OBVIOUSNESS HERE



To the extent that Maxeon argues that it would not be obvious to modify a back junction solar cell with a polysilicon emitter with an interfacial oxide layer, this argument has already been rejected by the PTAB in prior appeal proceedings from rejections of similar claims in related patent applications.

Specifically, SunPower, which assigned the 053 Patent family to Maxeon, filed two continuation applications that claimed priority to the 053 Patent. U.S.

App. No. 14/504,771 ("771 Application") and 16/460,035 ("035 Application") presented device claims corresponding to the 053 Patent's method claims. EX1003, Appendix A.

In the 771 Application, the Examiner rejected the solar cell device claims based on Meier (which taught a backside junction solar cell) as the primary reference in combination with (1) Okayasu, Borden, and Wenham or (2) Okayasu, Foglietti, Gan, and Wenham. Okayasu, Borden, Foglietti, Gan taught use of polysilicon emitters with intervening oxide layers. Maxeon appealed the rejections to the PTAB. In its appeal, SunPower retreated from the distinction made of Meier during the 053 Patent prosecuting and admitted that Meier did teach "forming the p+ layer 220 by *diffusion* into the substrate …" EX1005, 353 (emphasis added).[6] SunPower argued instead that while Okayasu disclosed a backside polysilicon layer, the combination with Meier would not result in the claimed invention because Okayasu's polysilicon layer is a BSF and not a backside junction like Meier. EX1005, 353-357.

The PTAB affirmed the Examiner's rejections, explaining that "[t]he Examiner employs Okayasu for its teaching of depositing a doped polysilicon layer

[6] To avoid a dispute over the distinction and admissions made by SunPower of Meier, CSI relies on Froitzheim here which clearly taught diffusion of boron from a dopant diffusion source layer to form the emitter.

on a doped substrate. The rejection is not based on a finding that the BSF layer (as opposed to the doped polysilicon layer) can be substituted for Meier's p-type emitter." EX1005, 516-17. The PTAB affirmed that the Examiner's finding that "Okayasu teaches that its method of depositing doped polysilicon layers is preferable to that of thermal diffusion (as taught in Meier) because it can be performed at lower temperatures, preventing damage to the substrate, and allows more accurate control of the emitter thickness." EX1005, 512. The PTAB further affirmed the Examiner's finding that although Meier as modified by Okayasu did not disclose an oxide layer between the polysilicon and substrate, other prior art references, Borden, Foglietti, and Gan, taught the inclusion and advantages of an oxide layer in between. EX1005, 513-519.

SunPower did not appeal the PTAB's decision to the Federal Circuit. Instead, SunPower filed the subsequent 035 Application, again presenting substantially similar device claims with some additional limitations (not relevant here). EX1018, 47-50. The Examiner again rejected these claims as obvious based on Meier in view of Okayasu, Borden, Wenham, Jordan, and Xi. EX1018, 207-222. SunPower/Maxeon again appealed the rejection, and the PTAB again affirmed the Examiner's rejection. EX1018, 227-270, 286-293. SunPower/Maxeon again *did not* appeal the PTAB's decisions to the Federal Circuit. EX1005, 522; EX1018, 295 (notices of abandonment).

Given that the PTAB has already found that replacing a diffused emitter with a deposited polysilicon emitter and a separate interfacial oxide layer obvious in the continuation applications, the PTAB should find the same here in this Petition. Although CSI is not relying on Okayasu for its teaching of a polysilicon layer like the Examiner in the two continuation applications, Gan and Kwark taught the polysilicon layer and its benefits, and thus Okayasu is not needed. Gan and Kwark additionally taught the benefits of the interfacial oxide layer. Thus, the combination relied on here is even stronger and more direct in its disclosure of the limitations of the 053 Patent than the prior art previously relied on by the Examiner to find similar claims unpatentable and affirmed by the PTAB.

XV. CONCLUSION

CSI therefore respectfully requests that trial be instituted and that claims 9-20 be canceled as unpatentable.

Dated: June 24, 2024

Respectfully submitted,

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CERTIFICATE OF COMPLIANCE

I hereby certify that this brief complies with the type-volume limitations of 37 C.F.R. § 42.24, because it contains 12,848 words (as determined by the Microsoft Word word-processing system used to prepare the brief), excluding the parts of the brief exempted by 37 C.F.R. § 42.24.

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PETITION FOR INTER PARTES REVIEW

OF U.S. PATENT NO. 8,878,053

Attachment A:

Proof of Service of the Petition

CERTIFICATE OF SERVICE

I hereby certify that on this 24th day of June 2024, a copy of this Petition, including all attachments, appendices and exhibits, has been served in its entirety by overnight mail on the following counsel of record for patent owner:

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Dated: June 24, 2024

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OF U.S. PATENT NO. 8,878,053

Attachment B:

List of Evidence and Exhibits Relied Upon in Petition

Exhibit #	Reference Name
1001	U.S. Patent No. 8,878,053 ("053 Patent")
1002	File History of U.S. Patent No. 8,878,053
1003	Declaration of Dr. Sanjay Banerjee
1004	Curriculum Vitae of Dr. Sanjay Banerjee
1005	File History of U.S. Patent Application No. 14/504,771 ("771 Application")
1006	EP1732142A1 to Armin Froitzheim ("Froitzheim")
1007	J.Y. Gan et al., "Polysilicon Emitters for Silicon Concentrator Solar cells," May 1990, Proceedings of the 21st IEEE-PVSC ("Gan")
1008	Kwark, Y. H. et al. "SIPOS Heterojunction contacts to silicon." 1984 International Electron Devices Meeting (1984): 742-745 ("Kwark")
1009	WO2009/094578 to Borden ("Borden")
1010	U.S. Provisional Patent Application No. 61/023,342 (EX1010) ("Borden Provisional"), filed January 24, 2008.
1011	U.S. Patent No. 6,262,359 to Meier ("Meier")
1012	Hartiti, B. et al., "Low Temperature Formation of Emitter and BSF by Rapid Thermal Co-Diffusion of P, Al or B." Dec. 5-9, 1994, IEEE, First WCPEC
1013	Sivohthaman, S. et al., "Rapid Thermal Processing of Conventionally and Electromagnetically Case 100 cm^2 Multicrystalline Silicon." May 13-17, 1996, IEEE, 25th PVSC
1014	U.S. Patent Pub. No. 2002/0142500 to Foglietti
1015	U.S. Patent Pub. No. 2005/0268963 to Jordan ("Jordan")
1016	Yablonovitch, Eli et al., "A Study of n^+-SIPOA:p-Si Heterojunction Emitters." Nov. 1985, IEEE Election Device Letters, Vol. EDL-6, No. 11 ("Yablonovitch")

Exhibit #	Reference Name
1017	Sinton, R. A. et al., "Design Criteria for Si Point-Contact Concentrator Solar Cells." Oct. 1987, IEEE Trans. on Electron Devices, Vol. ED-34, No. 10
1018	File History of U.S. Patent Application No. 16/460,035 ("035 Application")
1019	Luque, A. et al., "Handbook of Photovoltaic Science and Engineering." Wiley (2003)
1020	Lindholm, F.A., et al., "Heavily Doped Polysilicon-Contact Solar Cells." July 1985, IEEE Electron Device Letters, Vol. EDL-6, No. 7
1021	Silvestre, S. et al., "Series Resistance in Double-Polysilicon-Contacted Silicon Solar Cells." May 13-17, 1996, IEEE 25th PVSC
1022	Duerinckx, F. et al., "Defect passivation of industrial multicrystalline solar cells based on PECVD silicon nitride." 2002, Elsevier, Solar Energy Materials & Solar Cells
1023	Ashburn, P. et al., "Comparison of Experimental and Theoretical Results on Polysilicon Emitter Bipolar Transistors." July 1984, IEEE Trans. on Electron Devices, Vol. ED-31, No. 7
1024	U.S. Patent No. 6,998,288 to Smith ("Smith288")
1025	U.S. Patent No. 5,057,439 to Swanson ("Swanson439")
1026	June 21, 2022 Director Memo
1027	DocketNavigator Report
1028	Kass, D., "Fintiv Fails: PTAB Uses 'Remarkably Inaccurate' Trial Dates." (Fintiv study) https://www.law360.com/articles/1436071/print?section=ip
1029	Letter from Senator Thom Tillis to Andrew Hirshfeld, dated Nov. 2, 2021 (Senator Tillis Letter)

Exhibit #	Reference Name
1030	Nolan, M. et al., "Spectroscopic Investigations of Borosilicate Glass and Its Application as a Dopant Source for Shallow Junctions." 2000, Journal of The Electrochemical Society (ResearchGate)
1031	*Reserved*
1032	Declaration of Sylvia Hall-Ellis
1033	Curriculum Vitae of Sylvia Hall-Ellis
1034	Press Release, SunPower and Maxeon Solar Technologies Close Spin-Off Transaction, dated Aug. 27, 2020 https://newsroom.sunpower.com/2020-08-27-SunPower-and-Maxeon-Solar-Technologies-Close-Spin-Off-Transaction
1035	Patent Assignment
1036	SunPower Virtual Patent Marketing https://us.sunpower.com/solar-panels-technology/patents
1037	Patents | Maxeon Solar Technologies, Ltd. https://corp.maxeon.com/patents
1038	Press Release, SunPower and Maxeon Solar Technologies Close Spin-Off Transaction, dated Aug. 27, 2020 https://mediaroom.maxeon.com/2020-08-27-SunPower-and-Maxeon-Solar-Technologies-Close-Spin-Off-Transaction
1039	SunPower Maxeon Solar Panels https://sunpower.maxeon.com/int/solar-panel-products/maxeon-solar-panels
1040	Feldman, et al., "A Passivated Rear Contact for High-Efficiency n-Type Silicon Solar Cells Enabling High VocS and FF > 82%" at 1 (28th European PV Solar Energy Conference & Exhibition, Paris, Sept. 30 – Oct. 4, 2013) ("Feldman Paper").
1041	Green, M.A. et al., "High Efficiency N-Silicon Solar Cells Using Rear Junction Structures." IEEE (1993)

Exhibit #	Reference Name
1042	Murarka, S. et al., "Electronic Materials Science and Technology." 1989, Academic Press, Inc.
1043	OSTI Kwark Entry, https://www.osti.gov/biblio/5905985
1044	IEEE Xplore Kwark Entry, https://ieeexplore.ieee.org/document/1484603
1045	U.S. Patent No. 5,661,079
1046	IEEE Xplore Gan Entry, https://ieeexplore.ieee.org/document/111625
1047	IEEE Xplore Lemiti Entry, https://ieeexplore.ieee.org/abstract/document/520203/references#citations
1048	M. Lemiti, B. Semmache, Q. N. Le, D. Barbier and A. Laugier, "Physical properties of RT-LPCVD and LPCVD polysilicon thin films: application to emitter solar cell," Proceedings of 1994 IEEE 1st World Conference on Photovoltaic Energy Conversion – WCPEC (A Joint Conference of PVSC, PVSEC ands PSEC), Waikoloa, HI, USA, 1994, pp. 1375-1378 vol.2.
1049	IEEE Xplore Sivoththaman Entry, https://ieeexplore.ieee.org/document/564205
1050	P. Doshi, J. Mejia, K. Tate and A. Rohatgi, "Modeling and characterization of high-efficiency silicon solar cells fabricated by rapid thermal processing, screen printing, and plasma-enhanced chemical vapor deposition," in IEEE Transactions on Electron Devices, vol. 44, no. 9, pp. 1417-1424, Sept. 1997
1051	P. Doshi and A. Rohatgi, "18% efficient silicon photovoltaic devices by rapid thermal diffusion and oxidation," in IEEE Transactions on Electron Devices, vol. 45, no. 8, pp. 1710-1716, Aug. 1998
1052	A. Rohatgi, P. Doshi, J. Moschner, T. Lauinger, A. G. Aberle and D. S. Ruby, "Comprehensive study of rapid, low-cost silicon surface

Exhibit #	Reference Name
	passivation technologies," in IEEE Transactions on Electron Devices, vol. 47, no. 5, pp. 987-993, May 2000
1053	IEEE Xplore Hartiti Entry, https://ieeexplore.ieee.org/document/520502
1054	A. M. Jorgensen, T. Clausen and O. Leistiko, "Novel light trapping scheme for thin crystalline cells utilizing deep structures on both wafer sides [solar cells]," Conference Record of the Twenty Sixth IEEE Photovoltaic Specialists Conference - 1997, Anaheim, CA, USA, 1997, pp. 263-266
1055	August 9, 2002 International Search Report of PCT Publication No. 02/103810A1
1056	IEEE Xplore Doshi 1997 Entry, https://ieeexplore.ieee.org/document/622596/references#references
1057	IEEE Xplore Doshi 1998 Entry, https://ieeexplore.ieee.org/document/704369/references#references
1058	IEEE Xplore Rohatgi Entry, https://ieeexplore.ieee.org/document/841230/references#references
1059	IEEE Xplore Jorgensen Entry, https://ieeexplore.ieee.org/document/654079/references#references

PETITION FOR INTER PARTES REVIEW

OF U.S. PATENT NO. 8,878,053

Attachment C:

Listing of the Claims of 8,878,053

Claim Element	Claim Language
[9.a]	A method of fabricating a solar cell comprising:
[9.b]	forming a layer of polysilicon over a back surface of a silicon substrate;
[9.c]	forming a first dopant source layer over the layer of polysilicon;
[9.d]	diffusing dopants from the first dopant source layer to the layer of polysilicon to form a backside junction with the silicon substrate;
[9.e]	diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and
[9.f]	forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.
[10]	10. The method of claim 9 wherein the first dopant source layer comprises P-type dopants.
[11]	11. The method of claim 9 wherein the first dopant source layer comprises borosilicate glass.
[12]	12. The method of claim 9 wherein diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate.
[14.a]	14. The method of claim 9 further comprising: texturing the front surface of the silicon substrate; and

[14.b]	forming an antireflective layer over the textured front surface of the silicon substrate.
[15]	The method of claim 9 wherein the diffusion of dopants from the first dopant source layer to the layer of polysilicon and the diffusion of dopants into the front surface of the silicon substrate are performed in situ.
[16.a]	A method of fabricating a solar cell comprising:
[16.b]	forming an oxide layer over a back surface of a silicon substrate;
[16.c]	forming a layer of polysilicon over the oxide layer;
[16.d]	diffusing dopants into the layer of polysilicon to form a backside junction with the silicon substrate;
[16.e]	diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and
[16.f]	forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.
[17]	17. The method of claim 16 wherein diffusing dopants into the layer of polysilicon to form the backside junction with the silicon substrate comprises: forming a first dopant source layer over the layer of polysilicon; and diffusing dopants from the first dopant source layer into the layer of polysilicon
[18]	18. The method of claim 16 wherein diffusing dopants into the front surface of the silicon substrate comprises forming a second

	dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate.
[19]	19. The method of claim 16 further comprising: texturing the front surface of the silicon substrate.
[20]	20. The method of claim 19 further comprising: forming an antireflective layer over the textured front surface of the silicon substrate.