

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CANADIAN SOLAR INC.,
Petitioner

v.

MAXEON SOLAR PTE. LTD.,
Patent Owner

Case No. IPR2024-01039
U.S. Patent No. 8,222,516

PATENT OWNER RESPONSE

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<i>United Indus. Corp. v. Susan Mcknight, Inc.</i> , IPR2017-01687, Paper 31 (PTAB Jan. 22, 2019)	38

PATENT OWNER'S EXHIBIT LIST

Exhibit No.	Description
2001	<i>Intentionally Left Blank</i>
2002	Int'l Pub. No. WO 2009/094575 ("Borden-575")
2003	Gan, Jon-Yiew, Polysilicon emitters for silicon concentrator solar cells, Stanford University (July 1990) ("Gan Thesis")
2004	Results charted from DocketNavigator.com Document Search, run on October 8, 2024, for Motion to Stay Pending <i>Inter Partes</i> Review Decided by Judge Rodney Gilstrap
2005	Results charted from DocketNavigator.com Document Search, run on October 8, 2024, for Motion to Stay Pending <i>Inter Partes</i> Review Decided by Judge Rodney Gilstrap with "Stipulated/Agreed" Motions Removed
2006	Federal Court Management Statistics (June 30, 2024)
2007	Order Denying Maxeon Partial Motion to Dismiss, <i>Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.</i> , Case No. 2:24-cv-00210-JRG, Dkt. No. 26 (E.D. Tex. July 3, 2024)
2008	Docket Control Order, <i>Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.</i> , Case No. 2:24-cv-00210-JRG, Dkt. No. 33 (E.D. Tex. Aug. 7, 2024).
2009	Canadian Solar Inc.'s Invalidity Contentions, <i>Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.</i> , Case No. 2:24-cv-00210-JRG (E.D. Tex. Sept. 6, 2024).
2010	Feldman, et al., "A Passivated Rear Contact for High-Efficiency n-Type Silicon Solar Cells Enabling High VocS and FF > 82%"

	(28th European PV Solar Energy Conference & Exhibition, Paris, Sept. 30 – Oct. 4, 2013) (“Feldman”)
2011	Chieh-Wa Tsai, et. al, <i>Patent Analysis of High Efficiency Tunneling Oxide Passivated Contact Solar Cells</i> , 13 Energies 3060 (2020)
2012	File History of U.S. Patent No. 8,878,053
2013	File History of U.S. Patent Application No. 17/870,268
2014	Acharyya, S., Sadhukhan, S., Panda, T. et al. Performance analysis of different dielectrics for solar cells with TOPCon structure. J Comput Electron 21, 471–490 (2022) (Abstract) (available at: https://link.springer.com/article/10.1007/s10825-022-01866-0).
2015	<i>Intentionally Left Blank</i>
2016	<i>Intentionally Left Blank</i>
2017	<i>Intentionally Left Blank</i>
2018	<i>Intentionally Left Blank</i>
2019	<i>Intentionally Left Blank</i>
2020	Declaration of Douglas Ruby, Ph.D.
2021	Curriculum Vitae of Douglas Ruby, Ph.D.
2022	Declaration of Mary K. Bolin, Ph.D.
2023	Transcript of Deposition of Petitioner’s Expert Sanjay Banerjee, Ph.D. (March 20, 2025)

I. INTRODUCTION

Patent Owner, Maxeon Solar Private Limited (“Maxeon” or “Patent Owner”), submits its Patent Owner Response to Petitioner Canadian Solar Inc.’s (“CSI’s” or “Petitioner’s”) Petition for *Inter Partes* Review.

II. OVERVIEW OF THE ’516 PATENT

A. Background Art of the ’516 Patent

According to the ’516 patent, solar cells convert solar radiation to electrical energy. EX1001, 1:19-20.

The front side of the solar faces the sun. A solar cell with at least one metal contact on the front side is called a “front contact solar cell.” EX1001, 1:30-34.

B. The ’516 Patent

The ’516 patent discloses and claims a novel front contact solar cell with formed emitter. EX1001, Title.

The patent describes, with reference to Fig. 1, a cross-section of a solar cell in accordance with an embodiment of the present invention. EX1001, 1:66-67.

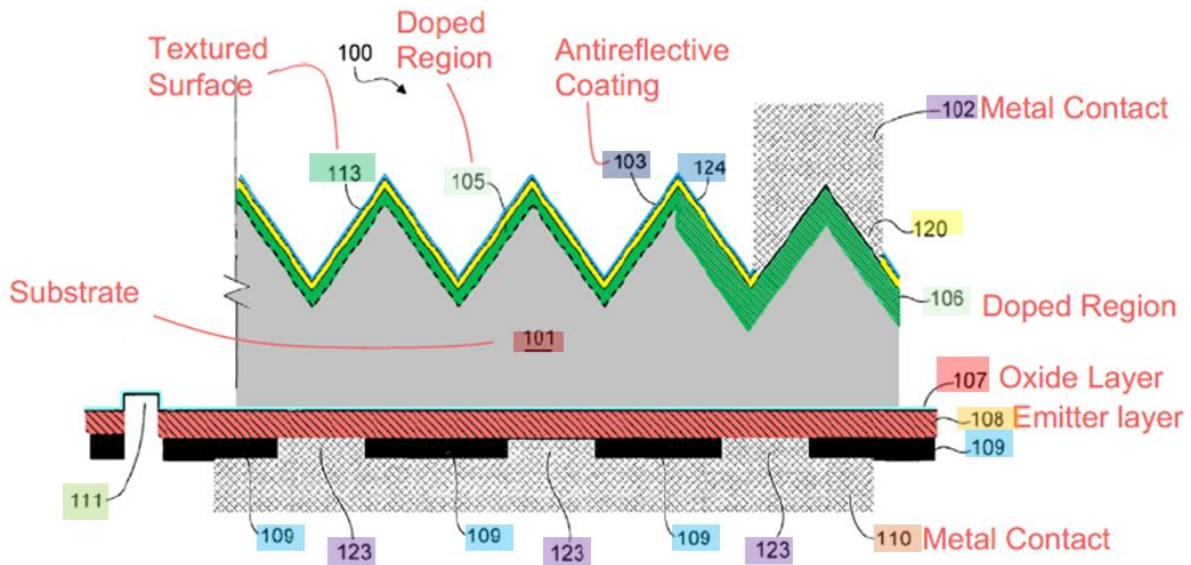


FIG. 1

EX1001, Fig. 1 (annotated).

In this embodiment, an N-type silicon substrate 101 is formed from a crystalline silicon wafer. EX1001, 3:50-55. The front side of the substrate is located at the top of Fig. 1 and faces the sun, the back side of the substrate is on the bottom of Fig. 1 and faces away from the sun. *Id.*, 2: 27. A tunnel oxide 107, which can be silicon dioxide, is provided on the back side of the substrate 101. *Id.*, 3:62-65.

A layer of polysilicon 108 is deposited on the tunnel oxide layer 107 to form the polysilicon emitter 108 (formed on the back side). EX1001, 3:66-4:2. A dopant source layer 461 (not shown in Fig. 1) is formed on the polysilicon emitter 108 (i.e., formed on the back side of the polysilicon emitter) and the dopant is later driven into the polysilicon with a drive-in step. *Id.*, 4:5-19. A capping layer 462

(not shown in Fig. 1) is formed over this dopant layer to keep the dopants from escaping during the dopant drive in process. *Id.*, 4:10-13. An edge isolation trench 111 is formed near the edge of the substrate 101 and is cut through the capping layer all the way through to contact a small area of the substrate 101. *Id.*, 4:20-27.

Exposed surfaces of the substrate 101 (on the front side) are etched to form pyramid 113 like structures. EX1001, 4:28-33. This etching step removes the previously applied layers 401 and 402, as can be seen in Figs. 4D and 4E. An N-type dopant source 412 is formed on the textured surface of the substrate. *Id.*, 4:34-38. The N-type dopants from dopant layer 412 are then driven-in to the substrate 101 forming N-type doping regions 105 and 106. This drive-in step also drives in the dopants from the doping source layer 461 into the back side of the polysilicon (polysilicon emitter 108), thus forming a **backside junction**. *Id.*, 2:37-41, 4:52-67.

The drive in step may be formed in-situ, which the patent explains can be “a single manual (i.e., by fabrication personnel) loading of the substrate 101 in a furnace or other single chamber of multi-chamber processing tool.” *Id.*, 5:1-8. After this drive in step, layers 461 and 462 become silicon dioxide layer 109 and the front side of the silicon becomes N-doped region 106. *Id.*, 4:58-60, 2:36-41. A thin thermal silicon dioxide layer 124 is provided as a passivation layer on the surface of the silicon substrate 101. *Id.*, 4:65-67.

An antireflective (also serving as a dielectric) coating of silicon nitride layer 103 is formed over the textured surface 113 after removal of the N-type dopant source layer 412. EX1001, 5:20-26. A front contact mask is then provided on silicon nitride layer 103 to create a pattern for forming contact holes 102. *Id.*, 5:28-32. A back contact mask 422 is used on the silicon dioxide layer 109 to create a pattern for the back side contact holes 123. The holes 102 and 123 are then etched away. *Id.*, 5:33-43.

A back side metal contact 110 is formed on the silicon dioxide layer 109 to fill the contact holes 123 and make electrical connection to the polysilicon emitter 108. EX1001, 5:48-55. Finally, a front side metal contact 120 is formed on the silicon nitride layer 103 to fill contact holes and make electrical connection to the substrate 101. *Id.*, 5:56-58.

While Fig. 1 illustrates a solar cell with an N-type substrate and a P-type polysilicon emitter forming a backside junction, the patent claims are broader than that and can encompass an N-type substrate and an N-type polysilicon emitter forming a backside junction. EX2020, ¶95. This is shown in the below comparison of independent claims 1 and 9.

Claim 1	Claim 9
1. A solar cell having a front side facing the sun to collect solar radiation during normal operation and a backside opposite the front side, the solar cell comprising:	9. A solar cell having a front side facing the sun to collect solar radiation during normal operation and a backside opposite the front side, the solar cell comprising:

an N-type silicon substrate;	a substrate
a textured surface on the N-type silicon substrate on the front side of the solar cell;	having a textured front surface;
an antireflective layer over the textured surface of the N-type silicon substrate;	
a P-type polysilicon emitter formed over the N-type silicon substrate forming a backside junction with the N-type silicon substrate;	an emitter layer formed over a back surface of the substrate, the emitter layer forming a backside junction with the substrate;
an oxide layer formed between the P-type polysilicon emitter and the N-type silicon substrate;	an oxide layer formed between the back surface of the substrate and the emitter layer;
a negative polarity metal contact making an electrical connection to the N-type silicon substrate from the front side of the solar cell; and	a first metal contact making an electrical connection to the substrate on the front side of the solar cell; and
a positive polarity metal contact making an electrical connection to the P-type polysilicon emitter from the back side of the solar cell.	a second metal contact making an electrical connection to the emitter layer of the backside of the solar cell, the first metal contact and the second metal contact being configured to allow an external electrical circuit to be powered by the solar cell.

EX1001, claims 1 (6:4-22) and 9 (6:42-57) (emphasis added).

As is shown above, claim 1 is directed toward specific N-type and P-type silicon and polysilicon layers, respectively. Claim 9, on the other hand, is silent with respect to the types of dopants used to dope the silicon and polysilicon layers. Therefore, considering the dopant sources, claim 9 is broader in scope than claim 1. Claim 9 is not limited to N-type silicon and P-type polysilicon layers. EX2020, ¶96.

C. Prosecution History of the '516 Patent

The '516 patent was filed as application number 12/070,742 on February 20, 2008. EX1001, Cover at (22).

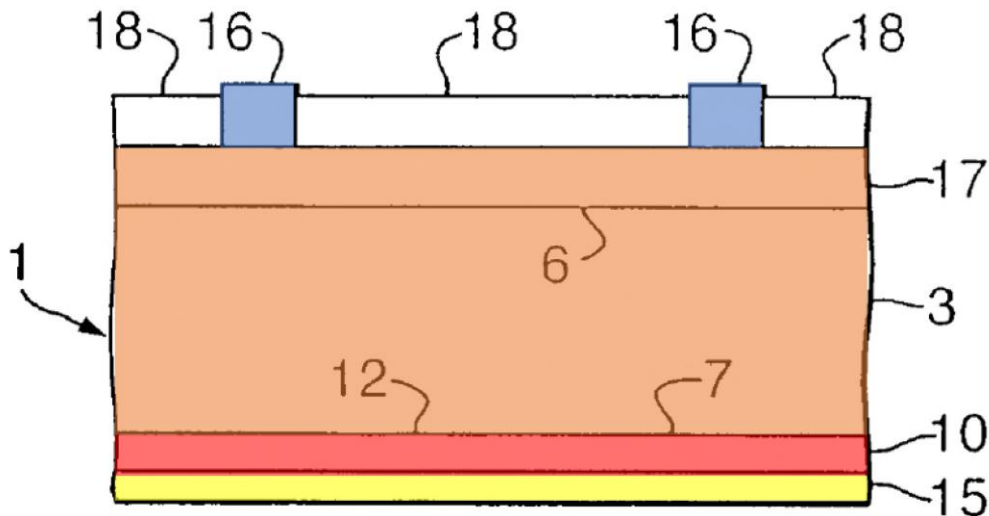
On December 24, 2009, following the applicant's election and amendment of claims, the Examiner issued a non-final rejection, citing various prior art combinations including U.S. Application No. 2006/0157103 ("Sheats"). EX1002, 59-65 (November 5, 2009 Requirement for Restriction/Election); *id.*, 68-70 (December 1, 2009 Amended Claims); *id.*, 74-84 (December 24, 2009 Non-final Rejection). The applicant eventually overcame the Examiner's rejections by specifying that the P-type polysilicon emitter is "formed over the N-type silicon substrate" and adding the limitation of "an oxide layer formed between the P-type polysilicon emitter and the N-type silicon substrate." *Id.*, 106-13 (March 19, 2010 Request for Reconsideration and Arguments/Remarks); *id.*, 116-29 (May 26, 2010 Final Rejection); *id.*, 131-41 (July 23, 2010 Request for Continued Examination).

On March 28, 2012, the Examiner issued a Notice of Allowance, stating "[t]he prior art of record lacks an oxide layer formed between an emitter and an oppositely doped substrate and a metal contact making an electrical connection to the substrate on the front light incident side of the solar cell." EX1002, 152.

III. THE PRIOR ART

A. Froitzheim (EX1006)

EP1732142A1 (“Froitzheim”) explains that in conventional (one sun) solar cells, an N-type emitter is located on the front side of the cell to form a P/N junction with P-type doped substrate. EX1006, ¶2. In contrast to such conventional cells, Froitzheim proposes to form the emitter at the rear (back) side of a solar cell creating a P/N junction on the rear side. EX1006, ¶8.



Petition, 40 (citing EX1006, ¶24) (annotations in Petition).

Specifically, the proposed solar cell includes an N-doped substrate 3 having a front side 6 and a rear side 7. EX1006, ¶24. Froitzheim provides a P-doped layer 10, *id.*, ¶22, which is actually a region of the substrate 3 doped with boron to form a P/N junction 12, *id.*, ¶25. A contact 15 covers substantially all of the rear side 7 of the cell. *Id.*, ¶27. The front side 6 of the substrate 3 is heavily doped with

an N-type dopant, *e.g.*, phosphorous, to provide a heavily N-doped layer 17 formed in the substrate in a region extending from the front side 6. *Id.*, ¶28. Contacts 16 are fabricated to contact the top side 6 of the underlying substrate 3, *id.*, and passivation layer 18 is formed over the exposed areas of the N-type doped layer 17, *id.*, ¶30.

Froitzheim teaches doping the front side 6 of the substrate 7 with an N-type dopant and doping the back side 7 of the same silicon substrate 3 with a P-type dopant. Petition, 21; EX1006, Abstract, ¶¶10, 11, 40. To drive the dopants into the rear side 7, Froitzheim teaches “the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between 1000 and 1100 degree C, to generate an oxide layer and to drive in the dopant.” EX1006, ¶42. This high temperature processing required by Froitzheim is important because, as explained below, the secondary references Gan and Kwark warn that treatment at such a high temperature must be avoided in order to attain a cell with the desired benefits of an oxide layer disclosed by Gan and Kwark.

Dr. Banerjee testified as to why Froitzheim preferred a temperature between 1000°C and 1100°C:

Q: Why would they prefer to use 1000 to 1100 degrees, do you know?

A: That’s because the higher the temperature, the higher is the diffusion coefficient which has a so-called Arrhenius

dependency...So higher temperature, more will be the diffusivity.

And that will determine the junction depth. But it also depends on diffusion time...

Q: So they're trying to achieve a higher diffusion. Is that correct?

A: . . . So you are trying to achieve a certain junction depth and a certain doping concentration. And the two main parameters, the diffusion temperature, and the diffusion time. Longer the diffusion time, higher the temperature. Everything else being the same, you'd get a deeper junction and the higher concentration of the surface. Shorter the temperature – or diffusion time and lower the temperature, you get a shallow junction. So those are the norms that a POSITA would use.

Q: Why would it be preferable to have a deeper junction?

A: It depends on the device design parameters. You'd want a junction of the appropriate depth to achieve the maximum efficiency in your solar cell."

EX2023, 85:7-87:1.

The 1000°C to 1100°C temperature preferred by Froitzheim maximizes the efficiency of the solar cell. Reducing the dopant drive in temperature to the lower temperatures taught by Gan and Kwark would reduce the efficiency of the solar cell described by Froitzheim. EX2020, ¶116.

Froitzheim does not disclose the use of an oxide and emitter layer recited in claims 1 and 9, and instead proposes using a silicon substrate 3 with doped regions on its front side and back side. Froitzheim also does not teach or suggest the use of

an oxide layer, e.g., a tunnel oxide, between the rear surface of the substrate and an emitter layer as required by claim 9. EX2020, ¶117.

Further, Froitzheim is the only example among the prior art applied by Petitioner which shows an operable solar cell. As discussed below, the Gan and Kwark references that Petitioner relies upon were research papers reporting on the theoretical use of an oxide layer and polysilicon layer formed on the back side of a crystalline silicon substrate. The Gan Thesis explains that neither Gan nor Kwark was able to create this structure so that it was reproducible and reliable. Given the discouraging results reported in the Gan Thesis and a divergence in processing temperature discussed below between Froitzheim's teachings and the teachings of Gan and Kwark, a POSITA would have little motivation to combine the unproven and unreliable teachings of Gan and Kwark to modify Froitzheim's solar cell according to their teachings. Moreover, any expectation of success from doing so would have been highly speculative. EX2020, ¶118.

CSI proposes to modify Froitzheim to include an oxide/polysilicon layer structure from Gan or Kwark to meet the emitter layer/oxide layer requirements of claim 9. However, CSI leaves unexplained how that would work since Froitzheim teaches driving in dopants at a high temperature that Gan and Kwark both teach must be avoided to obtain acceptable values of contact resistivity (ρ_c) and emitter saturation current density (J_0). EX2020, ¶119.

B. Gan (EX1007)

There are two Gan publications relevant to the Petition. One is a publication that CSI uses as the Gan reference in combination with Froitzheim. This is Gan et al., “*Polysilicon Emitters for Silicon Concentrator Solar cells*,” Proceedings of the 21st IEEE-PVSC (“Gan”), which was a paper presented in 1990 (EX1007, face, ii-iii). Petition, 36.

The other is the Gan Thesis (EX2003). The Gan Thesis was published and publicly available on the shelves in the Stanford Library on April 10, 1991, which is prior to the priority date of the ’516 patent. *See* EX2022, ¶23. Thus, a POSITA would have had knowledge of the Gan Thesis before that priority date. As explained below, the Gan Thesis is important for several reasons, including telling the complete story that the technology disclosed in Gan was considered theoretical, could not be reliably reproduced, and was not suitable for use in commercial solar cells. EX2020, ¶121.

CSI and its expert, Dr. Banerjee, have made clear that the proposed Froitzheim-Gan, Froitzheim-Kwark, and Froitzheim-Borden combinations start with the method described in Froitzheim to make the silicon substrate and stops prior to adding the dopants. Petition, 47, 62. Then the combinations switch to Gan/Kwark/Borden to “perform Gan’s steps of thin thermal oxide growth to form the interfacial layer and polysilicon deposition to form the polysilicon on the back

side of the water” after which the polysilicon would be doped using the steps in Froitzheim to form the polysilicon emitter. *Id.*, 47 (citing EX1003, ¶153, EX1007, 246); see also EX2023, 85:14-20 (“Q: Then after you add the oxide in [and] the polysilicon layer from Gan, then you would follow Froitzheim steps to add the dopant. Correct? A: Yes. Q: And would that be the same with Kwark and Borden? A: Well, this part essentially, yes.”).

Below are the specific steps used in Gan to add the oxide and polysilicon layers. Note, the steps with an “*” are the steps where Gan measures the J_o values. EX2020, ¶124.

- | | | |
|-------------------------------------|---|--|
| Start of process used in Gan |  | 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. |
| End of process used in Gan |  | 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 (annotated)

Step 4 (the anneal performed at 1050°C) causes breakup of the oxide layer. EX2020, ¶125. This step and step 10, the drive-in step, were the subject of Gan’s measurements to try to achieve acceptably low J_o values. EX1007, 246. The

anneal of step 4 is used to break up the thin oxide layer, and the second anneal performed at step 10 is used in Gan to drive in the dopants. EX2020, ¶125. This step 10 anneal is referred to as “the second-step anneal” in Gan’s Table 1 below. EX1007, 248.

Table 1: The effect of the second-step anneal on J_o and ρ_c .

	N-type		P-type	
	$J_{o,e} (\times 10^{-14} \text{ A/cm}^2)$	$\rho_c (\mu\Omega\text{-cm}^2)$	$J_{o,e} (\times 10^{-14} \text{ A/cm}^2)$	$\rho_c (\mu\Omega\text{-cm}^2)$
900 °C-4 hour	2.4	18	3.5	18
1000 °C-30 min	4.5	~ 6	8.2	3.8
1000 °C-60 min	7.9		10.5	

EX1007, 248, Table 1

Table 1 shows that as you increase the temperature and time in the second step anneal, the value of J_o increases, which is not a desired result. EX2020, ¶126.

The Petition states that “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” to grow the thin thermal oxide and form the polysilicon layer. Petition, 47. Paragraphs 40-42 of Froitzheim, which CSI used to add the dopant to the proposed combination and then drive in the dopants, state:

[0040] Providing a non-alloyed p-type doped region is done by a process which introduces dopant, preferably boron, only by diffusion into the rear surface of the body layer. . .

[0041] In general terms, a diffusion 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. . .

[0042] A suitable doping liquid is Siodop (TM) of Merck. Then the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between 1000 and 1100 degree C, to generate an oxide layer and to drive in the dopant.

EX1006, ¶¶40-42 (emphasis added).

Froitzheim's dopant drive-in steps are performed at preferably between 1000°C and 1100°C. EX1006, ¶42. CSI's expert testified that Froitzheim uses these high temperatures to get the correct dopant concentration and junction depth. EX2018, 81:7-83:10. However, at these dopant drive in temperatures, the value of adding the thin oxide layer of Gan is destroyed, to the point that Gan did not even test dopant drive in steps at greater than 1000°C. EX2020, ¶128.

Gan (EX1007) and the Gan Thesis (EX2003) both describe experiments that focused on trying to find the optimum temperature used in creating an interfacial oxide between a crystalline silicon substrate and a polysilicon layer and, more specifically, on how to break up the interfacial oxide a little, but not too much. Gan tried different anneal temperatures and durations and determined that above 900°C, the oxide breakup becomes too much. *See, e.g.*, EX1007, 248 (“Considering the significant increase of J_o caused by increasing the drive-in temperature from 900 to 1000°C. . .”); *see also id.* at (Table 1); EX2020, ¶122.

Gan examined “polysilicon emitters with a thermally grown interfacial oxide” for solar cells. Petition, 36 (citing EX1007, 245). Gan also taught that “a very thin oxide (interfacial oxide)” “[a]lways exists” between the polysilicon emitter and substrate.” EX1007, 245. More importantly, Gan Thesis teaches that “solar cells that were modeled or made in this study all suffered high contact resistance” and that “in the real solar cell runs, the situation grew even worse.” *See, e.g.*, EX2003, 129 (110 in original); *see also id.*, 135-136 (116-117 in original). Thus, the Gan Thesis debunks CSI’s narrative that Gan’s experiments with an interfacial oxide layer between a silicon substrate and a polysilicon layer were successful. Petition, 36-38 (citing EX1007; EX1003, ¶128); *but see* EX2020, ¶129.

Further, CSI ignores teachings in Froitzheim and Gan from which a POISTA would have understood the references are incompatible. First, based on title of Gan—“*Polysilicon Emitters for **Silicon Concentrator Solar Cells***”—a POSITA would know that Gan’s experiments pertained to the specialized field of concentrator cells discussed above. EX2020, ¶130. As Patent Owner’s expert explained, concentrator solar cells and one sun solar cells like Froitzheim are very different. EX2020, ¶¶48-50.

Next, CSI’s argument fails to account for the full extent of the failures that Gan encountered, as documented in the Gan Thesis: “[t]he thin-oxide growth

recipe used in this work was not reliable . . . It is then clear that a more reliable way of growing the thin oxide is needed.” EX2003, 126 (107 in original). For these and other reasons discussed below, CSI does not (1) show a reasonable expectation of success and (2) establish that a POSITA would have been motivated to combine Gan, focused on silicon concentrator solar cells with the one sun solar cell of Froitzheim. EX2020, ¶131.

CSI states that the combination “would have been well within the level of ordinary skill in the art” and involved “simple substitution of prior art elements according to known methods to yield predictable results.” Petition, 47-48 (citing EX1003, ¶¶154-55). The teachings in Gan and the Gan Thesis, as discussed below, has proven to not be true and inconsistent—even contrary—with the teachings in the applied art.

The Gan Thesis discusses the work described in Gan (EX1007) and repeatedly characterizes it as “theoretical,” and catalogs for a POSITA a variety of failures and unreliable results. *See, e.g.*, EX2003, 8 (Abstract); *id.*, 72 (53 in original). The unreliable results documented in the Gan Thesis belies CSI’s argument that the combination of Gan and Froitzheim would yield “predictable results.” *See* Petition, 47-48 (citing EX1003, ¶¶152-53).

Understanding that both Froitzheim and the ’516 patent are directed to one sun cells, CSI runs from the title of Gan, “*Polysilicon Emitters for Silicon*

Concentrator Solar Cells,” by noting that “[w]hile 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.’” Petition, 43 (citing Ex 1007, 249); EX1003, ¶130. However, in its Conclusion, Gan states “[f]rom the cell modeling, polysilicon emitters with these qualities can be useful for silicon **concentrator** solar cells.” Ex 1007, 249) (emphasis added). As Patent Owner’s expert explains, concentrator cells generate multiple times more free electrons than one sun solar cells, requiring concentrator solar cells to have a much lower resistive path from the substrate to the emitter, through the metal contacts and gridlines, than in a one sun solar cell. EX2020, ¶¶48-50; *id.*, ¶135. Tellingly, a review of the experimental and modeling results reported in the Gan Thesis, including mention of high current levels in the range of 100 A/cm² (equivalent to 2500 suns), EX2003, 28 (9 in original), indicate that the “modeling” referred to by Gan (EX1007) were of silicon concentrator solar cells. EX2020, ¶135. Thus, a POSITA would not look to modifying the one sun solar cell structure of Froitzheim with the teachings of Gan relating to concentrator solar cells. EX2020, ¶136.

Substantively, Gan is very specific about the effect of a high temperature anneal on the interfacial oxide layer between the silicon substrate and the polysilicon layers:

In either case, the oxide is not thermally stable; *i.e.*, it tends to break up during high temperature anneals. The breakup of the interfacial oxide has direct impact on both majority and minority carrier transport in the polysilicon emitter. This can be seen from the dependence on the specific contact resistivity (ρ_c) [6] and the emitter saturation current density (J_o) [1,2,3,4,5,6,7] upon either the anneal condition or the oxide integrity.

EX1007, 245.

Gan specifically says that when the temperature is high and the oxide loses its integrity, the ρ_c is low and the J_o is high:

With the effect of the interfacial oxide is negligible, such as when the interfacial oxide loses its integrity in high temperature anneals, the ρ_c is low ($\sim 2 \times 10^{-7}$ -cm²) [6] and the J_o is high ($\sim 1 \times 10^{-12}$) [1,3].

Conversely, when both the carriers are mostly blocked by the interfacial oxide, like for an intact chemical oxide (~ 15 Å), the ρ_c is high and the J_o is low.

EX1007, 245.

Gan teaches that it is optimal to have both a low J_o (emitter saturation current density) and ρ_c (contact resistivity), and this is achieved “when both carriers are mostly blocked by the interfacial oxide.” EX1007, 245, 249. What Gan is trying to determine is the “ ρ_c and J_o when only a small fraction of the interfacial oxide is broken.” *Id.* According to Gan “there always exists a very thin oxide (interfacial oxide), which can be the by-product of the cleaning process or is

grown intentionally . . . In either case, **the oxide is not thermally stable, *i.e.*, it tends to break up during the high temperature anneals.**” *Id.*, 245 (emphasis added). Gan explains that “[t]he first-step anneal, which serves to break up the oxide, was performed at higher temperature than that for the second-step anneal which aims for the dopant drive-in.” *Id.*

Gan ran multiple experiments for combinations of temperatures for the first anneal and the second anneal (for dopant drive in) and reported the results in Figure 6, which is a plot of ρ_c v. J_o , with a key in the top right that shows “the type of polysilicon emitter, the first-step anneal (temperature/minute), and the second-step anneal (temperature/minute).” EX1007, 249, Fig. 6. The goal was to provide low values for J_o .

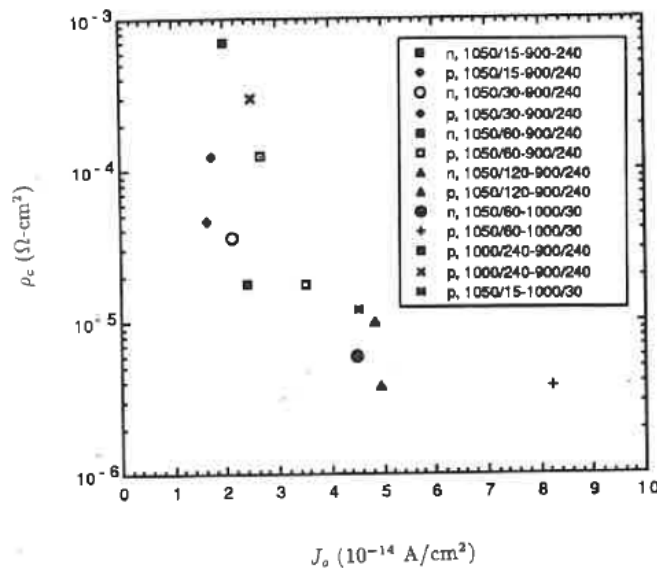


Figure 6: ρ_c - J_o of this work.

EX1007, Fig. 6.

This graph shows that the higher the temperature of the second step anneal (the anneal to drive the dopants into the polysilicon), the higher the J_o . In fact, this figure shows much lower J_o values for the 900 °C second anneal (“regime 1”) than for the 1000°C second anneal (“regime 2”). EX2020, ¶144. Gan then discusses this figure and observes for regimes 1 “ J_o is almost constant while ρ_c drops drastically” and for regime 2 “ ρ_c decreases very slowly and J_o increases in much faster pace.” EX1007, 249.

Gan also explains that the second step anneal is optimal when performed at “900 °C for 4 hours.” EX1007, 247. Gan further says “[considering the significant increase of J_o caused by increasing the drive-in temperature from 900 to 1000 °C, it is beneficial to use the two-step anneal to optimize J_o ” *Id.*

Gan provided further analysis of the experimental results in this Table 1, below. These results show that the higher the temperature of the second-step anneal and the longer its duration the worse the device works.

Table 1: The effect of the second-step anneal on J_o and ρ_c .

	N-type		P-type	
	$J_{o,e} (\times 10^{-14} \text{ A/cm}^2)$	$\rho_c (\mu\Omega\text{-cm}^2)$	$J_{o,e} (\times 10^{-14} \text{ A/cm}^2)$	$\rho_c (\mu\Omega\text{-cm}^2)$
900 °C-4 hour	2.4	18	3.5	18
1000 °C-30 min	4.5	~ 6	8.2	3.8
1000 °C-60 min	7.9		10.5	

EX1007, Table 1

Gan shows that as the temperature increases above 900°C, ρ_c decreases but J_o increases rather than decreases, such that anything above 900°C results in a

rapid decrease in the efficacy of the system. EX2020, ¶146. Since Froitzheim teaches that, to achieve dopant drive in for the rear surface of the substrate, “the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between **1000 and 1100** degree C, to generate an oxide layer and **to drive in the dopant**,” EX1006, ¶42 (emphasis added), combining Froitzheim and Gan either results in annealing at 900 °C, which is the lowest limit of Froitzheim’s teachings for the dopant drive in temperature, or performing the second step anneal (dopant drive in) at temperatures above 900°C that Gan teaches causes “ J_o [to] increase[] in much faster pace,” EX1007, 249, which would lead to poor cell efficiency. EX2020, ¶146.

Simply put, while Gan teaches best results are achieved when the second anneal to drive in dopants is at 900°C or below, Froitzheim teaches that the temperature to drive in dopants is preferably at 1000°C to 1100°C. Consequently, following Froitzheim’s teachings nullifies the benefits sought by Gan, and following Gan’s lower annealing temperature degrades the potential advantages achieved by Froitzheim’s teachings. *Id.*

Rather than being motivated to combine Froitzheim and Gan as proposed by CSI, a POSITA would have found the substance of the references’ teachings to be contradictory and would have rejected the combination. EX2020, ¶¶147-50.

C. Gan Thesis (EX2003)

Jon-Yiew Gan's thesis titled "*Polysilicon emitters for silicon concentrator solar cells*," published by the Stanford University in July 1990 ("Gan Thesis"), provides a more comprehensive review of the experiments and methodologies described in Gan (EX1007), *see, e.g.*, EX2003, 89-125 (70-106 in original) (Chapter 5), and provides significantly more details about the theory, experimental results, and conclusions set forth in Gan (EX1007). EX2020, ¶151.

The Gan Thesis was published and publicly available on the shelves in the Stanford Library on April 10, 1991, which is prior to the priority date of the '516 patent. *See* EX2022, ¶23. Thus, a POSITA would have had knowledge of the information in the Gan Thesis before that priority date.

The Gan Thesis discusses the findings in Kwark. *Compare* EX2003, Fig. 3.6 *with* EX1008, Fig. 4. The two figures are identical. EX2020, ¶153.

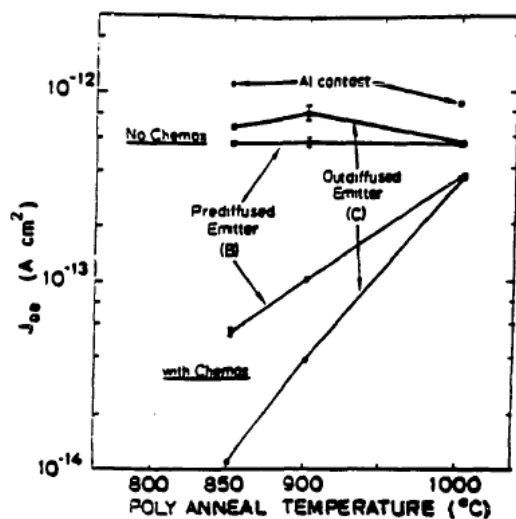


Figure 3.6: J_{oe} for n-type polysilicon emitters with and without a chemically grown interfacial oxide.

EX2003, Fig 3.6

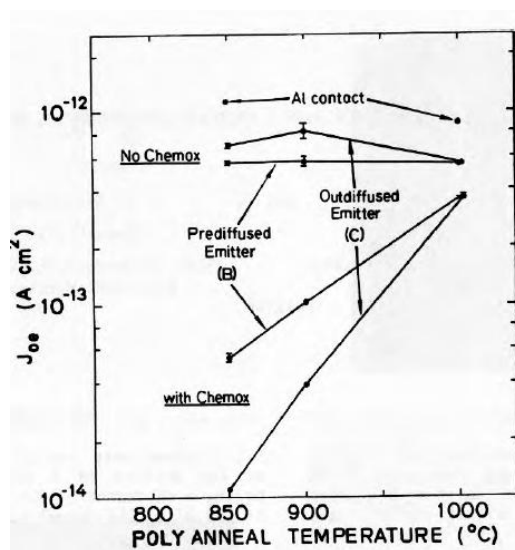


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

EX1008, Fig 4.

The Gan Thesis states:

[T]he very low J_o of the polysilicon SIS emitter has been demonstrated by other authors [7,10]. Figure 3.6 is the J_o of a polysilicon emitter reported by Kwark [7]. **Note that J_o of 1×10^{-14} A/cm² was observed on the device annealed at 850 °C. The rapid increase of J_o upon the anneal temperature is due to breakup of the interfacial oxide which will be discussed later.** A relatively intact interfacial oxide also explains a much lower J_{os} observed on the 900 °C-1 hour curve in Figure 3.3.

EX2003, 53 (34 in original) (emphasis added).

The Gan Thesis recognized the same phenomenon as in Gan (EX1007) and Kwark. From this data, a POSITA would understand that the alleged benefit of the interfacial oxide is not achievable at the preferred temperatures described for the anneal step in Froitzheim. EX2020, ¶155. Therefore, there would be no reasonable expectation of success from, or a motivation for combining Froitzheim and Kwark as proposed by CSI. *Id.*

Further, the Gan Thesis acknowledges inconsistent oxide growth during “ramp-up” and “stand-by” periods, and explains that “it is *possible* that the thin-oxide growth can be improved by performing the oxidation at lower temperatures such that the oxide rate can be controlled more precisely.” EX2003, 131 (112 in original). This was referenced by the Board in its Institution Decision. Institution Decision (Paper 13), 13.

At best, the Gan Thesis recognized that there were **possibilities** his theoretical results **could** be demonstrated. EX2020, ¶157. For instance, the Gan Thesis stated: “*Theoretically*, it is **possible** to make a polysilicon SIS emitter with an intact inter-facial oxide having low J_o and “acceptable” ρ_c simultaneously.” EX2003, 72 (53 in original) (emphasis added). Gan Thesis also stated “**[t]heoretically, a model was proposed** to make the polysilicon emitter with both low J_o ($\sim 3 \times 10^{-14}$ A/cm²) and low contact resistance ($\rho_c \leq 1 \times 10^{-5}$ Ω-cm²).” *Id.*, 8 (Abstract) (emphasis added). Gan Thesis further stated, “the polysilicon emitter with low J_o and ρ_c **can be made** with a very small fraction of interfacial oxide breakup.” *Id.*, 126 (107 in original) (emphasis added). Further, “[w]ith a few percentages of the interfacial oxide being broken, the ρ_c will be negligible for the application in concentrator solar cells. Under such a condition, there is a regime in which the J_o will not be affected by the oxide breakup because it is dominated by the recombination at the oxide interface. Thus it is **possible** for polysilicon SIS emitter to have both low J_o and ρ_c .” *Id.*, 88 (69 in original) (emphasis added).

Stepping back, however, a POSITA would recognize these musings in Gan Thesis were theories that fell far short of being reproducible. The lack of consistent success in experimental results demonstrate that the theories fell far short of supporting a reasonable expectation of success. EX2020, ¶157. This is

particularly true in view of experimental data reproduced in both the Gan Thesis and Kwark that show poor results when implementing the theories. *Id.*

Further, the Gan Thesis undermines the CSI's alleged motivation to combine Froitzheim and Kwark. *See, e.g.*, the above discussion of Figure 3.6 of the Gan Thesis and the identical Figure 4 from Kwark. To manufacture solar cells, one must have confidence that consistent, predictable, and reproducible results will be attained, not that there is a perceived theoretical possibility that the underlying technology may work occasionally. EX2020, ¶158. There is no evidence in either Kwark or Gan that they could repeatedly achieve the small amount of interfacial oxide breakup that was necessary for solar cells to perform reliably. *Id.*

The Gan Thesis stated “[i]n this chapter, we found that a consistent result of ρ_c is difficult to reproduce for the polysilicon emitter with a thermally grown interfacial oxide. This is mainly attributed to the fact that **our thin-oxide growth recipe is not reliable...**” EX2003, 135-36 (116-17 in original) (emphasis added). Gan Thesis was trying to obtain a low J_o of around $\sim 1 \times 10^{-14}$ A/cm². *See, e.g.*, EX2003, 8 (Abstract); *id.*, 22 (3 in original); *id.*, 41 (22 in original). This is understandable because Gan, Kwark, and the Gan Thesis are all trying to solve the same problem, namely a very small and consistent breakup of the interfacial oxide to achieve low J_o . In fact, the Gan Thesis showed that there was no known method for getting the oxide thickness reliably to obtain his best results. *Id.*, 138 (119 in

original) (“It appears that the oxide breakup depends **critically** on the interfacial oxide thickness. **The thin-oxide growth recipe used in this work was not reliable**; the oxide thickness between 15 and 20 Å have been found with the same growth condition. As a result, this contributes to the **fluctuation** of the ρ_c results.

It is then clear that a more reliable way of growing the thin oxide is needed.”)

(emphasis added); *id.*, 126 (107 in original) (“Although a thermally grown interfacial oxide seems **essential** for a polysilicon emitter to have both low J_o and ρ_c , **the breakup process is still difficult to control**. On several occasions, we have encountered **reproducibility problems**. For example, we find that the ρ_c is quite different between two separate experiments with identical processing

conditions. Even worse, **solar cells that were made in this study all suffered high contact resistance**. The problem is primarily due to insufficient oxide

breakup, and is caused by the fluctuation of the thickness of the interfacial oxide.”) (emphasis added); *id.*, 129 (110 in original) (“Later in the real solar cell

runs, the **situation grew even worse**...Although the $(J_{on} + J_{op})$ measured from those cells are between 8×10^{-14} and 4×10^{-14} A/cm², **the cell efficiency is greatly**

degraded by such a high emitter resistance.”); *id.* (“As shown in the figure, the cell is in fact plagued by two things: the high surface recombination velocity

($S = 58$ cm/sec), and high emitter resistance ($\rho_{cm} + \rho_{cp} = 1 \times 10^{-3} \Omega\text{-cm}^2$). . .

From the low emitter recombination and high emitter resistance, **it is clear that the**

interfacial oxide did not break as expected.”) (emphasis added); *id.*, 130 (111 in original) (“Although these results can be attributed to many other reasons, the following experiment shows that **the effect of the oxide thickness cannot be ignored. This, combined with the non-reliable oxide-growth recipe gives rise to the mishap of our solar-cell runs.”**) (emphasis added); *id.*, 133 (114 in original) (“It becomes clear that the wide fluctuation of our results is mainly due to the poor control over the oxide thickness.”); *id.*, 133-136 (114-117 in original) (“[W]e found that a consistent result of ρ_c is difficult to reproduce for the polysilicon emitter with a thermally grown interfacial oxide. This is mainly attributed to the fact that **our thin-oxide recipe is not reliable.”**); *id.*, 75 (56 in original) (“With a window so narrow, it is not possible to have good control over the characteristics of a polysilicon SIS emitter.”). One thing is clear based on a thorough reading of the Gan Thesis. He thought that one day it might be possible to achieve his best results, as well as those in his presentation and in Kwark, such that they could be used in one sun solar cells, but Gan and Kwark were a long way off still. EX2020, ¶159.

Figure 4 of Kwark (figure 3.6 of the Gan Thesis) shows that the results of a polysilicon layer with Chemox rapidly degrades at temperatures over 850°C as shown by the increase in J_o . Further, Froitzheim teaches that for dopant drive in “the wafer is treated in an atmosphere that contains oxygen at a temperature of 900

to 1200 degree centigrade, preferably between 1000 and 1100 degree C, to generate an oxide layer and to drive in the dopant.” EX1006, ¶42. The temperature ranges exceed the temperatures Gan and Kwark both recognized as the maximum temperatures possible before a rapid loss of effectiveness occurred. EX2020, ¶160.

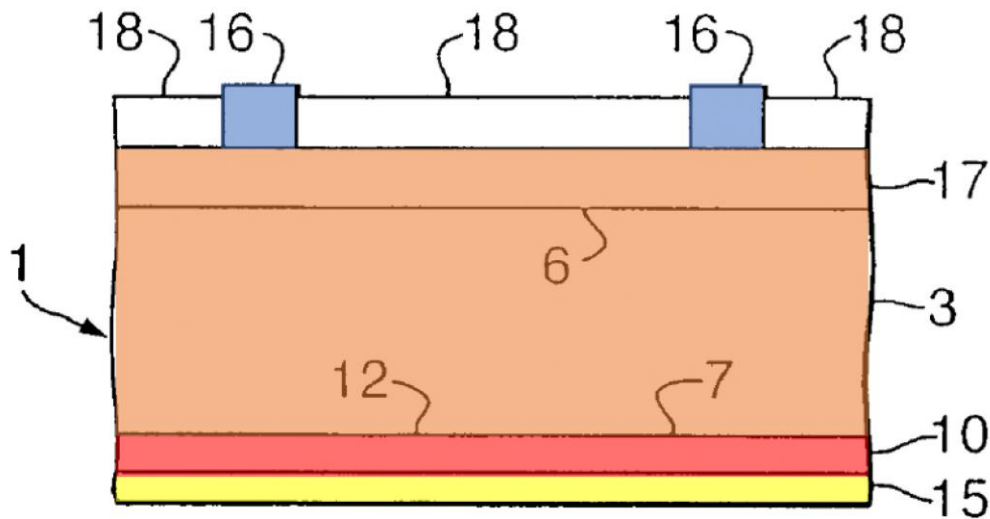
Simply, the Gan Thesis established that the processes found in Gan and Kwark would not achieve good results consistently or reliably, especially at the temperatures used by Froitzheim. Consequently, a POSITA would not have had a reasonable expectation of success with the proposed Froitzheim-Gan and Froitzheim-Kwark combinations, and therefore would not have been motivated to combine them. EX2020, ¶161.

D. Kwark (EX1008)

Kwark et al. is titled “SIPOS Heterojunction Contacts to Silicon” and published in the International Electron Devices Meeting, 742-745 (1984) (“Kwark”). EX1008. Like Gan, Kwark does not concern a commercial embodiment of a solar cell, but focuses on the results of laboratory experiments relating to possible ways to increase the efficiency of a solar cell. EX2020, ¶162.

Contrary to CSI’s claim, Kwark does not teach or suggest that “modify[ing] Froitzheim’s emitter [(i.e., a diffused in-substrate emitter)] to be a polysilicon emitter with an oxide layer” “would be an improvement.” Petition, 60 (citing

EX1003, ¶189); EX2020, ¶163. In Froitzheim the “in-substrate emitters” are the area 10 in which P-dopants are (boron) diffused into the back side 7 of the substrate 3 and the area 17 at the front side 6 of the substrate 3 in which N-type dopants (phosphorous) are diffused. EX1006, ¶¶25, 41 (disclosing boron diffusion); *id.*, ¶¶24, 44 (disclosing phosphorus diffusion).



Petition, 40 (citing EX1006, ¶24) (annotations in Petition).

Froitzheim makes no reference to polysilicon emitters and Kwarck does not mention in-substrate emitters at all, never mind suggesting improvements thereto. EX2020, ¶164. CSI incorrectly attributes the “potential improvements” and “good results” that Kwarck found for SIPOS emitter contacts to a polysilicon emitter. Compare Petition, 7 (citing EX1008, 742) (“Incorporation of [SIPOS] films into the emitter structure of an NPE bipolar transistor had been found to reduce the emitter saturation current fifty fold (3); this translates into potential improvements

of energy conversion for solar cells”) with EX1007, 742 (“That the γ films [(aka $\gamma=0$ SIPOS contacts)] produced such good results was surprising since POLY films of comparable thickness should yield a J_{oe} an order of magnitude larger.”).

In particular, CSI argues that Kwark showed that in the “SIPOS contact structure[,]. . . the increase in J_{oe} at higher temperature is not as severe as for the devices in Fig. 4,” which shows the polysilicon emitter. Petition, 60-61; *but see* EX1007, 743; *see also id.* at Figs. 4, 6 (below). However, in both cases, J_o values increase to unacceptably high levels for anneal temperatures above 900°C.

EX2020, ¶165.

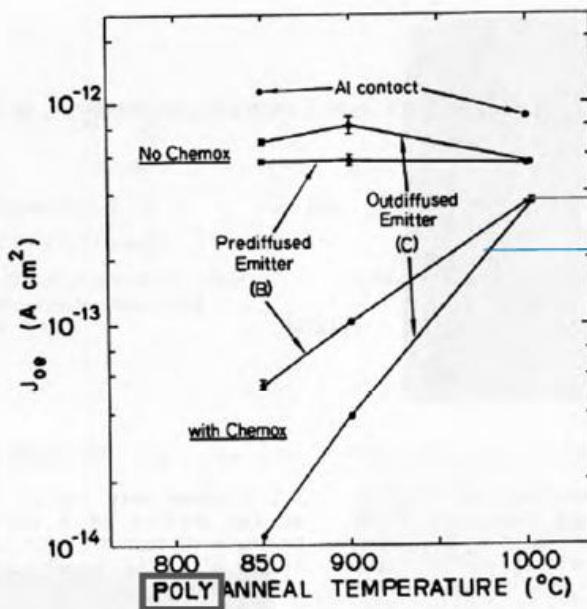


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

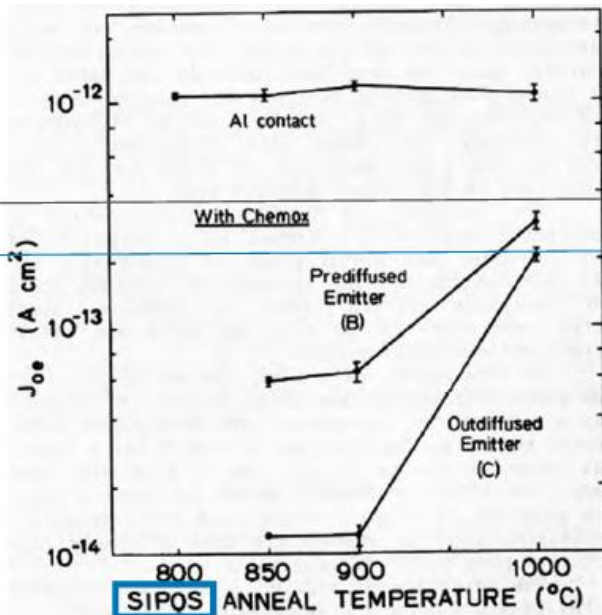
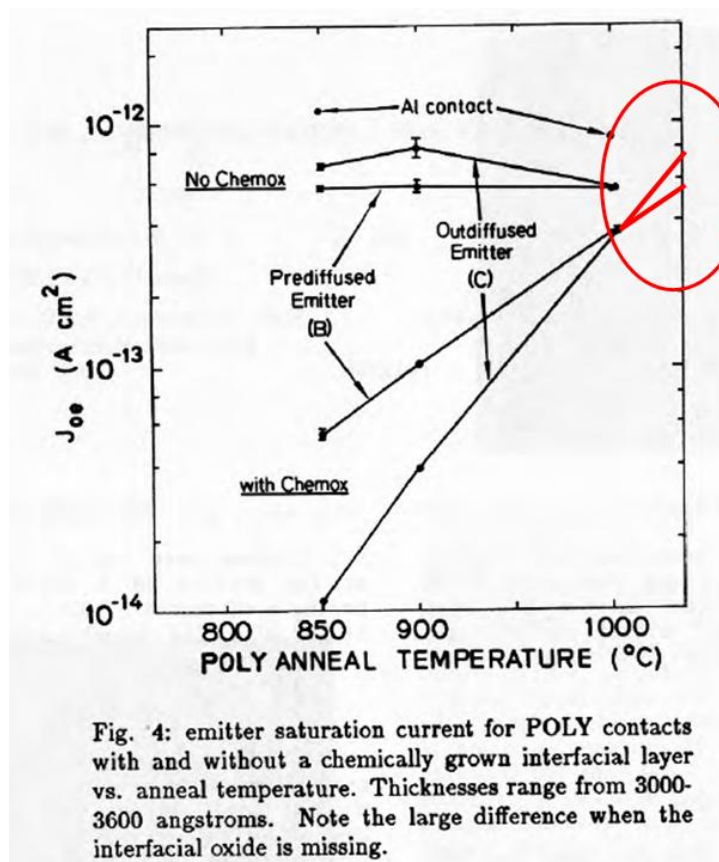


Fig. 6: emitter saturation current vs. anneal temperature for SIPOS contacts with a chemically grown interfacial oxide. The $\gamma = 0$ SIPOS layer is 3300 angstroms thick.

EX1008, Figs. 4, 6 (annotated).

In other words, CSI posits that KwarK recognized that polysilicon emitters with a chemical oxide (“Chemox”) rapidly lose performance in saturation current density after high temperature anneal steps above 850°C whereas the SIPOS emitters are more resilient, but still lose their ability to passivate the contacts above 900°C. EX2020, ¶166.

However, a POSITA would have understood from KwarK that the Chemox layer works far better when subject to low temperature anneals, 900°C or below. EX2020, ¶167; EX1008, 742 (“In fact for devices annealed at 900°C/13 min, there is very little dependence on γ as seen in Fig. 2, although increasing the anneal temperature to 1000°C adversely affected J_{oe} .”), *id.*, 743 (“Fig. 4 displays the resulting J_{oe} as a function of annealing temperature for emitter B which has a Gaussian (3×10^{19} surface concentration, 1 micron depth into 5×10^{16} background) emitter diffused prior to the POLY deposition and emitter C which relied solely on outdiffusion from the doped POLY to form the base-emitter junction”), *id.* (“To this is added a component due to outdiffusion from the heavily doped POLY which becomes increasingly significant for annealing temperatures above 900°. . . At 1000° this outdiffusion is **severe** enough to dominate the J_{oe} which accounted for the lack of difference between emitters B and C.”) (emphasis added).



EX1008, Fig. 4 (annotated).

A POSITA would also have known that Froitzheim teaches “the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between 1000 and 1100 degree C, to generate an oxide layer and to drive in the dopant.” EX2020, ¶168; EX1006, ¶42. CSI posits applying the drive in process of Froitzheim, i.e., preferably at 1000°C and 1100°C. But like Gan, Kwark’s data show that such high temperatures would negate the alleged benefits attributed to Kwark’s use of a low temperature for driving in the dopants. EX2020, ¶168. As can be seen above, when the emitter lines are

extended (in red) into Froitzheim's preferred temperature ranges, the alleged benefits from the use of Chemox are lost. *Id.*

Further, the Gan Thesis, reports on test results when using Chemox, and specifically considers Kwark's Fig. 4 analysis. *Compare* EX1008, Fig. 4 with EX2003, Fig. 3.6. As discussed below, the Gan Thesis demonstrates that the results suggested by Kwark are not predictably or consistently reproducible.

A POSITA would not have chosen to modify Froitzheim by adopting the Chemox layer and polysilicon layer disclosed by Kwark and driving in the dopants at the temperatures suggested by Froitzheim, 900°C to 1200°C with 1000°C to 1100°C being preferred. EX2020, ¶170. A POSITA would have been further deterred from that combination by the poor results reported in the Gan Thesis from annealing within the temperatures taught in Froitzheim for dopant drive in. *Id.*

E. Borden¹ (EX1009)

PCT Patent Publication WO2009/094578 ("Borden"), published in 2009, is directed to improving HIT cells (Heterojunction with Intrinsic Thin layer cells) by

¹ The Borden Provisional does not support all of Borden's disclosures. *See, e.g.*, EX1009, ¶¶4 (disclosing, without support, the thickness of the two amorphous silicon layers), 5 (disclosing, without support, a junction at the front surface), 18 (specifying, without support, that the thin dielectric layer may be a tunnel oxide,

providing it with “a controlled interface [] through insertion of a thin tunnel oxide.” EX1009, Abstract. Borden claims priority to U.S. Patent Application No. 61/023,342 filed on January 24, 2008. *Id.* at Cover (30).

Borden distinguishes HIT cells from polysilicon emitter cells: “[Polysilicon emitter solar cells] do not provide the heterojunction and its benefit of a higher cell voltage due to the higher bandgap of a-Si.” EX1009, ¶16.

F. Foglietti (EX1014)

U.S. Patent Publication US 2002/0142500 (“Foglietti”), published in 2002, relates to a “method of forming an interfacial oxide in a bipolar transistor.” EX1014, Abstract.

Foglietti teaches that in NPN bipolar transistors using polysilicon emitter on a monocrystalline silicon substrate, an interfacial oxide sometimes forms at the

and that the tunneling current be “between the substrate and a-Si layer”), 24 (disclosing, without support, PE-CVD and doping), 25 (disclosing, without support, returning of process to steps S306 or S308), 19, 21, 22 (disclosing entire paragraphs without support); *see also id.* at Fig. 3 (elimination of arrow from step S308 to step S310). To the extent these unsupported Borden disclosures are referenced in Petitioner’s arguments or expert’s declarations, the Board should not consider them.

interface of the two. EX1014, ¶2. Foglietti also teaches that the interfacial oxide has tunneling properties:

[T]he interfacial oxide is generally less resistive with respect to majority carriers (electrons) moving from the emitter region of the transistor into the base region than minority carriers (holes) moving from the base region into the emitter region. This phenomena is due to the tunneling probability of electrons being greater than the tunneling probability of holes.

EX1014, ¶3; *see also id.*, ¶4 (“[T]he majority carrier in an NPN transistor, can tunnel through the interfacial oxide 22 from the emitter 20 to the base 14, and contribute to the collector current I_C .”); *id.*, ¶5 (“[T]he interfacial oxide 22 blocks holes 32 from passing therethrough from the base 14 to the emitter 20, thus working to minimize the base current I_B .”).

Thus, Foglietti concludes, the interfacial oxide “may be modeled as a selective diode. . . wherein the electrons 30 see a forward biased, conductive path, and the holes 32 see a reverse-biased, non-conductive path.” EX1014, ¶5. This purported improvement, according to Foglietti, is “substantially dependent upon various properties of the interfacial oxide.” *Id.*, ¶6. For example, the interfacial oxide cannot be too thick so as to reduce the number of electrons which can tunnel therethrough, or too thin so as to insufficiently block the hole current. *Id.* Foglietti also teaches that “the oxide integrity also may play a role in device performance,” and mentioned that “if the interfacial oxide is fractured or becomes discontinuous,

resulting in oxide islands, such fractures will be random and not repeatable from device to device; consequently, such fracturing causes unreliable transistor gain performance.” *Id.*, ¶7.

IV. THE LEVEL OF ORDINARY SKILL

Maxeon applies the level of ordinary skill in the art CSI proposes. Petition, 3-4.

V. CLAIM CONSTRUCTION

Maxeon applies the plain and ordinary meaning of claim terms in this Patent Owner Response.

VI. CLAIMS 9-11 OF THE '516 PATENT ARE PATENTABLE UNDER MEIER, OKAYASU, BORDEN, AND JORDAN (GROUND 1)

CSI’s first ground based on Meier, Okayasu, Borden, Jordan (“Ground 1”) fails on both procedure and merit.

A. CSI Improperly Incorporates Arguments Not of Record

The Board found that, on Ground 1, CSI fails to carry its burden to “identify and explain sufficiently the evidence that supports the challenge to each claim.” Paper 13, 28. Specifically, CSI improperly relies on “previous conclusions of an Examiner and the Board when addressing different claims in a different patent,” and “improperly attempts to incorporate arguments and evidence from ten paragraphs in Dr. Banerjee’s declaration into the Petition.” *Id.*, 27 (discussing CSI’s arguments under Meier, Okayasu, Borden, and Jordan).

CSI cannot remedy that failure now. “It is of the utmost importance that petitioners. . . adhere to the requirement that the initial petition identify ‘with particularity’ the ‘evidence that supports the grounds for the challenge to each claim.’” *Intelligent Bio-Sys., Inc. v. Illumina Cambridge Ltd.*, 821 F.3d 1359, 1369 (Fed. Cir. 2016) (quoting 35 U.S.C. § 312); *cf. Netflix, Inc. v. DivX, LLC*, 84 F.4th 1371, 1377 (Fed. Cir. 2023) (affirming finding Petitioner waived arguments not raised in Petition); *Colas Sols., Inc. v. Blackledge Emulsions, Inc.*, 759 F. App’x 986, 989 (Fed. Cir. 2019) (non-precedential) (quoting *Intelligent Bio-Sys.*, 821 F.3d at 1369; 35 U.S.C. §312(a)(3)) (finding that, consistent with *Intelligent Bio-Sys.*, the Board did not abuse its discretion by finding a petitioner’s theory waived); *United Indus. Corp. v. Susan Mcknight, Inc.*, IPR2017-01687, Paper 31 at 29 n.13 (PTAB Jan. 22, 2019) (arguments “not presented sufficiently in the Petition [are] waived”).

B. CSI’s Fails to Show that a POSITA Would Have Been Motivated to Combine Borden with Meier/Okayasu

CSI’s arguments on Ground 1 should be rejected on improper incorporation of arguments alone. Nevertheless, for completeness of record, Ground 1 also fails on the merits.

CSI’s proposed Meier-Okayasu Froitzheim-Borden combination uses polysilicon emitters, but Borden’s purported benefits are directed to HIT cells, not polysilicon emitter cells. Petition, 23 (referencing Okayasu’s “method of

depositing doped polysilicon layers”); *id.*, 24 (referencing Borden’s tunnel oxides).

Borden’s Abstract, when read in full, makes this clear:

Benefits of the invention include that it provides a controlled interface for the HIT cell through insertion of a thin tunnel oxide. Moreover, the tunnel oxide prevents epitaxial growth of amorphous silicon, allowing it to remain amorphous for the optimum band structure. Still further, it provides a layer to protect the surface from plasma damage during deposition of the a-Si layer.

EX1009, Abstract (emphasis added). Amorphous silicon (also referenced as “a-Si layer” in Borden) is a feature of “[a] typical HIT type solar cell.” *Id.*, ¶[0004]; *see also id.* at Fig. 1B; EX2020, ¶181. Borden also expressly distinguishes HIT cells from polysilicon emitter cells “[Polysilicon emitter solar cells] do not provide the heterojunction and its benefit of a higher cell voltage due to the higher bandgap of a-Si.” EX1009, ¶ [0016].

In other words, the purported benefit of the thin tunnel oxide is solely related to amorphous silicon, and amorphous silicon is not present in the proposed Meier-Okayasu combination. Thus, a POSITA would not have been motivated to insert Borden’s tunnel oxide layer (unclear whether this is CSI’s proposed “interfacial oxide layer”) on the proposed Meier-Okayasu combination because Borden’s purported benefits would not have been applicable. EX2020, ¶182.

VII. CLAIMS 9-11 OF THE '516 PATENT ARE PATENTABLE UNDER MEIER, OKAYASU, FOGLIETTI, GAN, AND JORDAN (GROUND 2)

For the same reason discussed in section VI.A, CSI fails to carry its burden in challenging claims based on Meier, Okayasu, Foglietti, Gan, and Jordan (“Ground 2”). Paper 13, 27 (discussing CSI’s arguments under Meier, Okayasu, Borden, and Jordan); *id.*, 28 (finding CSI’s arguments under Meier, Okayasu, Foglietti, Gan, and Jordan to be “problematic for the same reasons”).

The inquiry should end here, but for completeness of record, Ground 2 also fails on the merits. A POSITA would not have been motivated to combine Foglietti and Gan because they pursue opposite goals.

Foglietti’s goal is to form “an interfacial oxide with good control which maintains its integrity during subsequent processing.” EX1014, [0010]; EX2020, ¶184. Specifically, Foglietti teaches that, “under appropriate circumstances,” an interfacial oxide allows majority carriers (electrons) to tunnel through, but blocks minority carriers (holes). *Id.*, [0003-5]. These appropriate circumstances include the interfacial oxide being thin enough to permit majority carriers to tunnel through, but not too thin so as to form an insufficient barrier, *id.*, [0004, 6], and the interfacial oxide maintaining its integrity and not become “fractured” or “discontinuous,” *id.*, [0003].

Gan's goal, on the other hand, is to break up the interfacial oxide. EX2020, ¶185. According to Gan, contact resistance is high "[w]hen the interfacial oxide is intact [and] tunneling is the only process available for the majority carriers to pass through the interfacial oxide." EX1007, 249. Striking a balance between low recombination and low resistance, Gan uses annealing to break the interfacial oxide "by a very small fracture." *Id.*, Abstract. According to Gan, this break-up creates "additional highly conductive channels" "between the polysilicon and the substrate in the broken regions." *Id.*, 249.

In other words, Foglietti teaches maintaining an interfacial oxide's integrity to enable majority carrier tunneling, but Gan discloses breaking up the interfacial oxide to create different processes for the majority carriers to pass through. Thus, a POSITA would not have been motivated to combine the two incompatible references. EX2020, ¶186; *Intel. Corp. v. PACT XPP Schweiz AG*, 2023 WL 2198649, at *3 (Fed. Cir. Feb. 24, 2023) (non-precedential) ("[E]vidence that the teachings and concepts of the prior art were (either actually or apparently) incompatible such that a skilled artisan would not have reasonably expected to succeed in combining those teachings is relevant to the obviousness analysis."); *see also In re Hedges*, 783 F.2d 1038, 1041 (Fed. Cir. 1986) (citation omitted) ("It is impermissible within the framework of section 103 to pick and choose from any one reference only so much of it as will support a given position, to the exclusion

of other parts necessary to the full appreciation of what such reference fairly suggests to one of ordinary skill in the art.”); *Panduit Corp. v. Dennison Mfg. Co.*, 810 F.2d 1561, 1568 (Fed. Cir. 1987) (“Among legal standards for determining scope and content of the prior art, for example, are: a prior patent must be considered in its entirety, i.e., as a whole, including portions that would lead away from the invention in suit.”).

VIII. CLAIMS 9-12 OF THE ’516 PATENT ARE PATENTABLE UNDER FROITZHEIM AND GAN (GROUND 3)

Ground 3 states that claims 9-12 are obvious based on Froitzheim and Gan. Petition, 3.

A POSITA would not have been motivated to combine Froitzheim and Gan because if Froitzheim’s anneal temperatures for dopant drive in were used with an emitter as taught by Gan to include an interfacial oxide and polysilicon layers the result would exhibit high resistivity and high recombination and precluded Gan’s purported benefit. A POSITA would also have been discouraged by the lack of predictable results in reliably growing Gan’s oxide layer. EX2020, ¶188. Lastly, the incompatibility in the temperatures taught in Froitzheim and Gan for annealing to drive in dopants would have been readily apparent to a POSITA.

A. A POSITA Would Not Have Had a Reasonable Expectation of Success in Combining Froitzheim and Gan

1. Froitzheim's Anneal Temperature on Gan's Oxide Layer Would Have Led to High Resistivity and High Recombination

Gan shows the J_o increases too rapidly as the temperature increases above 900°C. Anything above 900°C, however, produces a rapid increase in J_o , which is disastrous for solar cells. EX2020, ¶¶123-29; *id.*, ¶¶138-50.

Gan identifies polysilicon emitters with $J_o \leq 5 \times 10^{-14}$ A/cm² and $\rho_c \sim 1 \times 10^{-5}$ Ω/cm² to be “quite useful for silicon for silicon concentrator solar cells.” EX1007, 249. CSI bases its motivation to combine on the “usefulness” asserted by Gan. Petition, 44 (citing EX1007, 249). But Gan explains that to obtain useful polysilicon emitters his experiments “indicate that the interfacial oxide is only broken by a very small fraction.” EX1007, Abstract; *see also id.*, 248 (“[B]ecause the dominant recombination is likely at the oxide interface, it implies that the oxide must only be broken by very a small [*sic*] fraction.”).

To achieve the desired values, Gan's device undergoes two anneals: a first-step anneal at 1050 °C following polysilicon deposition, and a second-step anneal at 900-1000 °C to drive-in dopants. *See, e.g.*, EX1007, 246 (steps 4, 10).

However, Gan's data and the interpretation of it in Gan indicates that extending the temperature range above 900°C and up to 1000°C is over inclusive. Gan's experimental data does not support such a high temperature and Gan ultimately

concludes that the second step anneal should be performed **at or below 900°C**.

See § III.B (citing EX1007, 246; *id.*, 249; *id.* at Table 1); *see also* EX2020, ¶¶TBD.

Gan focused on the lower temperature for the drive in anneal because Gan observed that “ J_o increases with the temperature and time of the second-step anneal.” EX1007, 248.

Gan’s measurements show that, when the second-step anneal is conducted at higher than 900°C, a P-type polysilicon emitter incurs suboptimal ρ_c and J_o values. EX2020, ¶191. For example, at 900°C, Gan’s P-type polysilicon emitters have a ρ_c of $18 \mu\Omega\text{-cm}^2$ (or $1.8 \times 10^{-5} \Omega/\text{cm}^2$), which is higher than the value of $\rho_c \sim 1 \times 10^{-5} \Omega/\text{cm}^2$ that Gan deems to be useful. EX1007, 248 (Table 1).

To the extent CSI argues that Gan discloses its findings to be “useful for silicon solar cells” when ρ_c is lower than $5 \times 10^{-5} \Omega/\text{cm}^2$, EX1007, 249, it should be noted that Gan specifies at that ρ_c (current density), “the potential drop across the contact is negligible as long as the current density is less than $100 \text{ A}/\text{cm}^2$,” *id.* CSI does not support or even allege that its proposed Froitzheim-Gan combination would feature Gan’s specified current density. Thus, a POSITA would not have found that ρ_c value to be relevant. EX2020, ¶192.

Table 1, below, shows that dopant drive in at 1000 °C, even for 30 minutes, results in a value of J_o of $5 \times 10^{-14} \text{ A}/\text{cm}^2$ for N-type and $8 \times 10^{-14} \text{ A}/\text{cm}^2$ for P-type, both of which are higher than what Gan used in his simulations for

concentrator cells of 2×10^{-14} A/cm² for N-type and 3.5×10^{-14} A/cm² for P-type.”

Table 1: The effect of the second-step anneal on J_o and ρ_c .

	N-type		P-type	
	$J_{o,e}$ ($\times 10^{-14}$ A/cm ²)	ρ_c ($\mu\Omega$ -cm ²)	$J_{o,e}$ ($\times 10^{-14}$ A/cm ²)	ρ_c ($\mu\Omega$ -cm ²)
900 °C-4 hour	2.4	18	3.5	18
1000 °C-30 min	4.5	~ 6	8.2	3.8
1000 °C-60 min	7.9		10.5	

EX1007, 248 (Table 1) (annotated); EX2020, ¶193. The values of Gan’s P-type polysilicon emitter are relevant because CSI proposes replacing “Froitzheim’s rear P-type diffused *in-substrate* emitter with a rear P-type deposited *polysilicon* emitter plus the beneficial interfacial oxide layer.” Petition, 31 (emphasis in original).

CSI proposes that the Froitzheim-Gan combination would undergo a second-step (dopant drive in). EX2020, ¶195. According to Froitzheim: “the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between **1000 and 1100** degree C, to generate an oxide layer and to drive in the dopant.” EX1006, ¶42 (emphasis added); EX2020, ¶195-96.

Thus, even at the lowest anneal temperature Froitzheim discloses, 900°C, the resulting Froitzheim-Gan combination would yield a value of ρ_c that is higher than what Gan finds useful. If a POSITA followed Froitzheim’s preferred temperature of 1000°C to 1100°C, the resulting Froitzheim-Gan combination would also yield a value of J_o that Gan finds unacceptable. EX2020, ¶197.

Further, the Gan Thesis discloses that a desirable value for J_o should be even lower: “cell efficiency . . . is hardly affected by the emitter recombination when J_o is below 1×10^{-14} A/cm²; however, it falls off rapidly as the J_o increases over 1×10^{-14} A/cm².” EX2003, 3. The Gan Thesis explains that values of J_o this low were not achieved. EX2020, ¶198; EX2003, Fig. 5.21, 103 (original).

A POSITA would have either avoided the high temperature dopant drive in anneal of Froitzheim to achieve Gan’s purported benefits or would have annealed at Froitzheim’s high temperatures and found no benefit in combining Froitzheim and Gan. Thus, there would have been no motivation to combine. EX2020, ¶¶199-200.

2. *A POSITA Would Not Have Been Able to Consistently Grow Gan’s Oxide Layer*

A POSITA would also not have a reasonable expectation of success in combining the polysilicon and oxide layer emitter of Gan with the silicon wafer disclosed in Froitzheim. This was established by the Gan Thesis, which expands on the subject matter disclosed in Gan. EX2020, ¶201.

The Gan Thesis stated “[i]n this chapter, we found that a consistent result of ρ_c is difficult to reproduce for the polysilicon emitter with a thermally grown interfacial oxide. This is mainly attributed to the fact that **our thin-oxide growth recipe is not reliable**...In order to have **predictable** results, it appears that a

precise control of the oxide thickness is necessary.” EX2003, 135-136 (116-117 in original) (emphasis added).

The Gan Thesis explains that an object was to obtain a low J_o of around $\sim 1 \times 10^{-14}$ A/cm². *See, e.g.*, EX2003, 8 (Abstract); *id.*, 22 (3 in original); *id.*, 41 (22 in original). This is understandable because Gan, Kwark, and the Gan Thesis are all trying to solve the same problem, namely a very small and consistent breakup of the interfacial oxide to achieve low J_o . EX2020, ¶203. In fact, Gan showed that there was no known method for getting the oxide thickness reliably to obtain his best results. *Id.*, 138 (119 in original) (“It appears that the oxide breakup depends **critically** on the interfacial oxide thickness. **The thin-oxide growth recipe used in this work was not reliable**; the oxide thickness between 15 and 20 Å have been found with the same growth condition. As a result, this contributes to the **fluctuation** of the ρ_c results. **It is then clear that a more reliable way of growing the thin oxide is needed.**”) (emphasis added); *id.*, 126 (107 in original) (“Although a thermally grown interfacial oxide seems **essential** for a polysilicon emitter to have both low J_o and ρ_c , **the breakup process is still difficult to control**. On several occasions, we have encountered **reproducibility problems**. For example, we find that the ρ_c is quite different between two separate experiments with identical processing conditions. Even worse, **solar cells that were made in this study all suffered high contact resistance. The problem is**

primarily due to insufficient oxide breakup, and is caused by the fluctuation of the thickness of the interfacial oxide.”) (emphasis added); *id.*, 129 (110 in original) (“Later in the real solar cell runs, the **situation grew even worse**...Although the $(J_{on} + J_{op})$ measured from those cells are between 8×10^{-14} and $4 \times 10^{-14} A/cm^2$, **the cell efficiency is greatly degraded by such a high emitter resistance.**”); *id.* (“As shown in the figure, **the cell is in fact plagued by two things: the high surface recombination velocity ($S = 58$ cm/sec), and high emitter resistance ($\rho_{cm} + \rho_{cp} = 1 \times 10^{-3} \Omega\text{-cm}^2$).** . . . From the low emitter recombination and high emitter resistance, **it is clear that the interfacial oxide did not break as expected.**”) (emphasis added); *id.*, 130 (111 in original) (“Although these results can be attributed to many other reasons, the following experiment shows that **the effect of the oxide thickness cannot be ignored. This, combined with the non-reliable oxide-growth recipe gives rise to the mishap of our solar-cell runs.**”) (emphasis added); *id.*, 133 (114 in original) (“It becomes clear that the wide fluctuation of our results is mainly due to the poor control over the oxide thickness.”); *id.*, 133-36 (114-17 in original) (“[W]e found that a consistent result of ρ_c is difficult to reproduce for the polysilicon emitter with a thermally grown interfacial oxide. This is mainly attributed to the fact that **our thin-oxide recipe is not reliable.**”); *id.*, 75 (56 in original) (“With a window so

narrow, it is not possible to have good control over the characteristics of a polysilicon SIS emitter.”).

A POSITA would read the Gan Thesis and determined that the experiments discussed in Gan produced unreliable results, created “mishap[s],” produced reproducibility problems, and the good results were only theoretical. EX2020, ¶205.

B. A POSITA Would Not Have Been Motivated to Combine Froitzheim and Gan

Because there would have been no basis for a reasonable expectation of success in combining Froitzheim with Gan to produce the claimed solar cell with a substrate, emitter, and oxide layer between the two as required by claim 9, a POSITA would not have been motivated to combine the references. EX2020, ¶206.

As discussed in § VIII.A.1, a POSITA would not be motivated to combine the Gan reference with the Froitzheim reference because any advantages in J_o and ρ_c proposed by Gan would be unattainable as a consequence of the temperature range, including the preferred temperature range, disclosed by Froitzheim. EX2020, ¶207.

As discussed in § VIII.A.2, a POSITA would not be motivated to combine the Gan reference with Froitzheim because the Gan Thesis, which discusses the work of the Gan reference in greater detail, tells the POSITA that the oxide layer

required in the combination consistently fails, is unreliable, and at best remains a theoretical improvement. EX2020, ¶208.

Finally, a POSITA would also not be motivated to combine Gan with Froitzheim because Gan is directed to concentrator solar cells. Concentrator cells generate multiple times more free electrons than one sun solar cells requiring concentrator solar cells to have a much lower resistive path from the substrate to the emitter, through the metal contacts and gridlines, than in a one sun solar cell. EX2020, ¶¶48-50. But the high current levels taught in the Gan Thesis indicate that the “modeling” referred to by Gan (EX1007) were of silicon concentrator solar cells. *Id.*, ¶ 132. Thus, a POSITA would not look to modifying the one sun solar cell manufacturing method of Froitzheim with the teachings of Gan relating to concentrator solar cells. *Id.*, ¶209.

C. Froitzheim and Gan Teach Away from Each Other

A POSITA would not have combined Froitzheim with Gan because with regard to the temperatures to use to drive in dopants they direct the POSITA to take opposite paths. *In re Urbanski*, 809 F.3d 1237, 1244 (Fed. Cir. 2016)) (“A reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken by the applicant.”); *In re Mouttet*, 686 F.3d 1322, 1333 (Fed. Cir. 2012) (holding that a

“reference that properly teaches away can preclude a determination that the reference renders a claim obvious.”). As discussed in §VIII.A.1; their conflicting disclosures about annealing temperature would have discouraged a POSITA from combining Froitzheim with Gan or Kwark.

It is irrelevant that Gan does not expressly discourage use of high anneal temperatures. “What a reference teaches a person of ordinary skill is not . . . limited to what a reference specifically ‘talks about’ or what is specifically ‘mentioned’ or ‘written’ in the reference. Under the proper legal standard, a reference will teach away when it suggests that the developments flowing from its disclosures are unlikely to produce the objective of the applicant's invention.”

Syntex (U.S.A.) LLC v. Apotex, Inc., 407 F.3d 1371, 1380 (Fed. Cir. 2005) (citations omitted). Gan shows that the J_o increases too high as the temperature increases above 900°C, yet Froitzheim requires annealing temperature at 900°C and above. EX2020, ¶¶169-81.

Here, as discussed in §VIII.A.1, at the lowest anneal temperature Froitzheim discloses, *i.e.*, 900°C, the resulting Froitzheim-Gan combination would yield a value of ρ_c that is higher than what Gan finds useful. Further, at Froitzheim’s preferred temperature of 1000°C to 1100°C, the resulting Froitzheim-Gan combination would yield a value of J_o that is much higher than what Gan finds useful. EX2020, ¶¶189-97. Even though the temperatures taught by Gan and

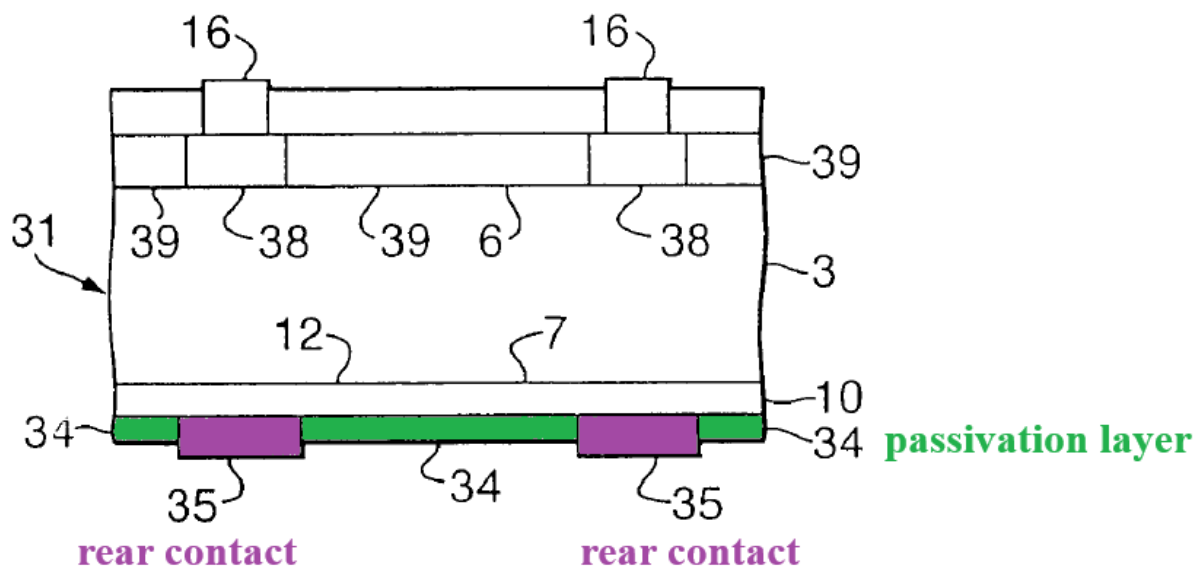
Froitzheim may meet at a point in the road, one teaches to go south from there and the other says to go north.

D. The Proposed Froitzheim-Gan Combination Would Not Have Met Limitations in Claim 12 of the '516 Patent

The proposed Froitzheim-Gan combination also fails to satisfy the limitations in claim 12 of the '516 patent.

1. The Board Should Not Consider CSI's Proposed Froitzheim-Gan Combination (Claim 12)

The Board should not consider CSI's proposed Froitzheim-Gan combination under claim 12, which is based on an alternative embodiment of Froitzheim. Petition, 55-56 (citing and illustrating EX1006, Fig. 3). This alternative embodiment includes an additional passivation layer 34 and rear contacts 35 in a finger structure. EX1006, [0033].



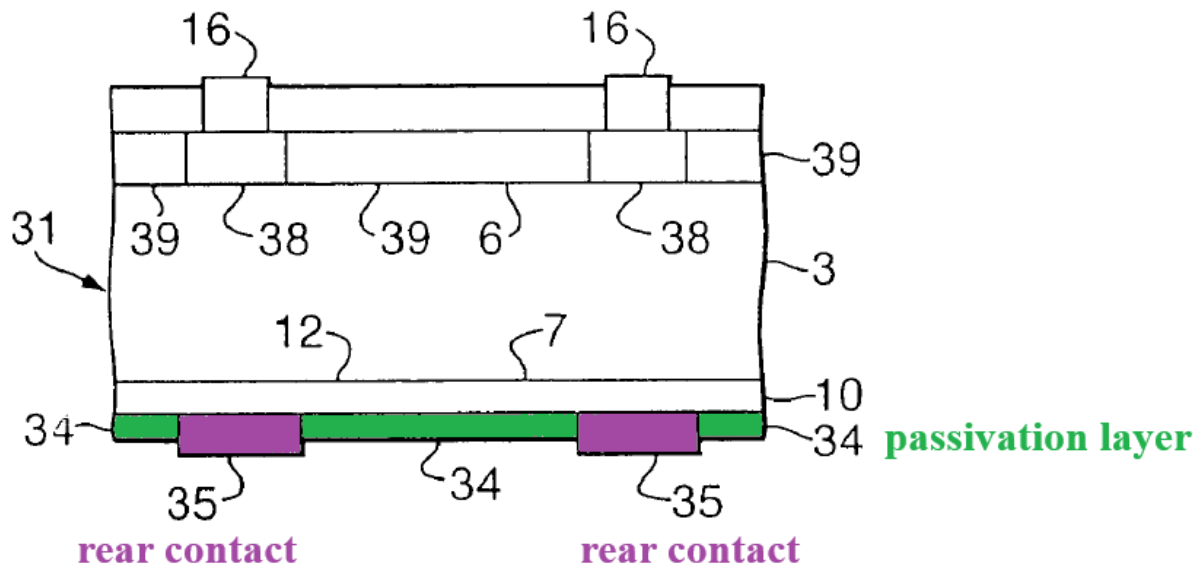
EX1006, Fig. 3 (annotations added).

CSI fails to explain how this alternative embodiment would be modified with Gan, or whether a POSITA would have been motivated to perform such modifications. Thus, the Board should not consider CSI's proposed Froitzheim-Gan combination using this alternative embodiment. *Smith & Nephew, Inc. v. Conformis, Inc.*, IPR2017-00545, Paper 8 at 13-14 (PTAB July 13, 2017) (citation omitted) (declining to “parse through the Petition and attempt to develop arguments on Petitioner’s behalf” because it is “inappropriate for the Board to take the side of the Petitioner to salvage an inadequately expressed ground proposing an alternative rationale.”); *Dominion Dealer Sols., LLC v. Autoalert, Inc.*, IPR2013-00225, Paper 15 at 4 (PTAB Oct. 10, 2013) (it is Petitioner’s responsibility “to explain specific evidence that support[s] its arguments, not the Board’s responsibility to search the record and piece together what may support Petitioner’s arguments.”).

2. *The Proposed Froitzheim-Gan Combination Does Not Include a “second metal contact” with “silver formed over a layer of silicon dioxide” (Claim 12)*

CSI improperly equates Froitzheim’s disclosure of its rear contacts 35 forming *after* the passivation layer with the claim 12 limitation of “silver form[ing] *over* a layer of silicon dioxide.” Petition, 56-57 (citing EX1006, ¶¶19, 33, 50). Froitzheim in fact discloses and illustrates that its passivation layer 34 is arranged *between* the rear contact 35 fingers. EX1006, Fig. 3; *id.*, ¶33 (“Between the fingers

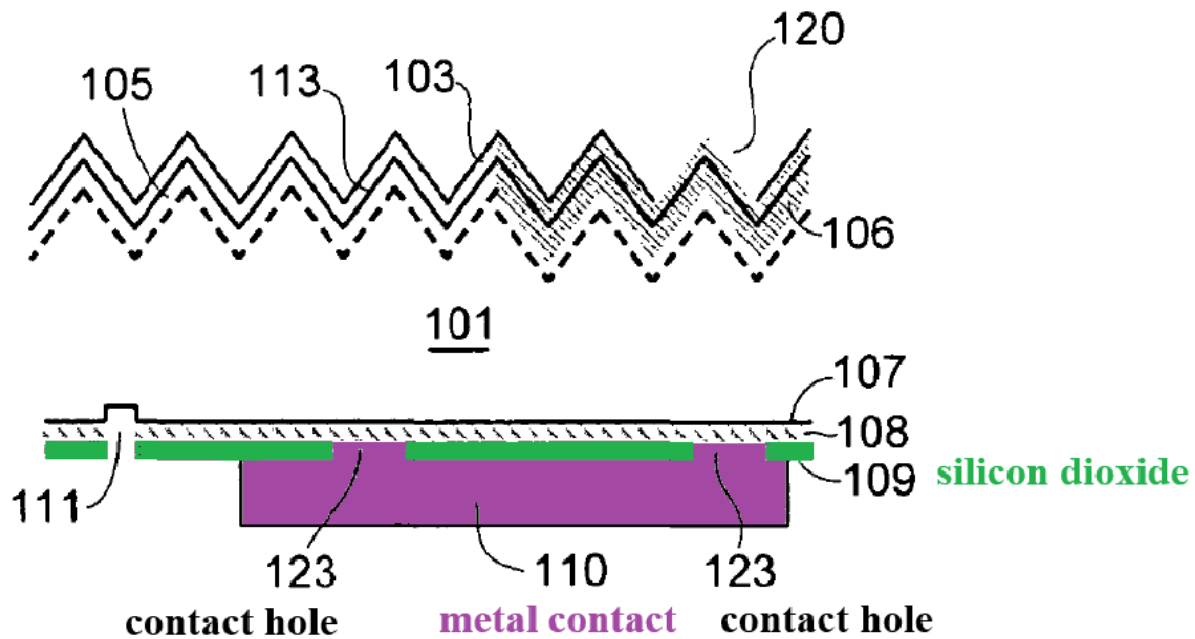
a passivation layer 34 is arranged”). This is achieved by screen printing and firing squeegee paste “in order to make electrical contact with the p region.” *Id.*, [0049]. In the firing process, the squeegee paste pierces the passivation layer to reach the emitter layer 10 to form the electrical contact. EX2020, ¶211.



EX1006, Fig. 3 (annotations added).

In contrast, in the '516 patent, the rear metal contact is formed *over* a layer of silicon dioxide because there are metal holes ensuring electrical contact.

Specifically, the '516 patent describes that, first, “contact holes 120 and 123 are formed by removing exposed portions of the silicon nitride layer 103 and the silicon dioxide 109 in a contact etch step.” EX1001, 5:38-40. Next, “the metal contact 110 is formed *on* the silicon dioxide layer 109 to fill the contact holes 123 and make electrical connection to the polysilicon emitter 108.” *Id.*, 5:48-50 (emphasis added).



EX1001, Fig. 4L (annotated). As shown, parts of the metal contact 110 overlap with the silicon dioxide layer 109. This overlap is not present in Froitzheim's Figure 3 or description thereof, and thus, the proposed alternative Froitzheim-Gan combination would not meet the limitation of claim 12. EX2020, ¶214.

IX. CLAIMS 9-12 OF THE '516 PATENT ARE PATENTABLE UNDER FROITZHEIM AND KWARK (GROUND 4)

Ground 4 states that claims 9-12 are obvious based on Froitzheim and Kwark. Petition, 3.

A. CSI Fails to Show Why a POSITA Would Have Been Motivated to Combine Froitzheim and Kwark

1. A POSITA Would Not Have Expected a Reasonable Expectation of Success in Combining Froitzheim and Kwark

One feature of Kwark is the use of a Chemox layer, which Kwark teaches only works at low temperature anneals. EX1008, 742 (“In fact for devices annealed at 900°C/13 min, there is very little dependence on γ as seen in Fig. 2, although increasing the anneal temperature to 1000°C adversely affected J_{oe} .”), *id.*, 743 (“Fig. 4 displays the resulting J_{oe} as a function of annealing temperature for emitter B which has a Gaussian (3×10^{19} surface concentration, 1 micron depth into 5×10^{16} background) emitter diffused prior to the POLY deposition and emitter C which relied solely on outdiffusion from the doped POLY to form the base-emitter junction”), *id.* (“To this is added a component due to outdiffusion from the heavily doped POLY which becomes increasingly significant for annealing temperatures above 900°. This is apparent if one notes that the increase in J_{oe} for emitter B can be accounted for by the J_{oe} of emitter C at the same temperature. At 1000°C this outdiffusion is **severe** enough to dominate the J_{oe} which accounted for the lack of difference between emitters and C.”). *Id.*, 743 (emphasis added). The annealing process referenced above is the step to drive in the dopants into the polysilicon layer. EX2023, 110:8-111:7.

However, as discussed in § VIII.A.1, Froitzheim teaches “the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between 1000 and 1100 degree C, to generate and oxide layer and to drive in the dopant.” EX1006, ¶42. In other words, at the temperatures Froitzheim says should be used to drive in the dopant, the benefits alluded to by Kwark would be lost. EX2020, ¶217.

Like Gan, Kwark examined emitter saturation current, J_{oe} , as a function of annealing temperature. Kwark’s J_{oe} and Gan’s J_o are the same; they both use the unit of current density Amperes per square centimeter. *See, e.g.*, EX1007, Abstract (Gan disclosing “ $J_o \leq 5 \times 10^{-14}$ A/cm²”); EX1008, Abstract (Kwark disclosing “ J_{oe} , values of 2×10^{-14} A/cm²”); EX2020, ¶218; EX2023, 107:17-108:3.

Similar to Gan, Kwark disclosed a desirable J_{oe} , value of 2×10^{-14} A/cm². EX1008, Abstract; *see also id.*, 743 (discussing attaining “[e]mitter saturation currents of $1-2 \times 10^{-14}$ A/cm²” for “POLY with Chemox and for both SIPOS contact structures.”). Kwark also discloses “a baseline J_{oe} of 5×10^{-14} A/cm²” for “[p]rediffused’ emitter B.” *Id.*

Like Gan, Kwark identified higher-than-desired J_{oe} values at anneal temperature of 900°C and above, and provided his analysis in the following chart:

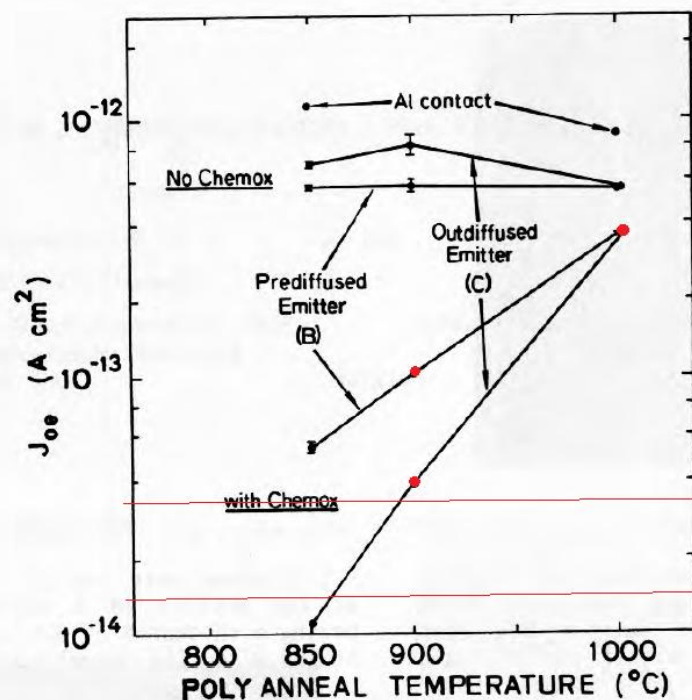
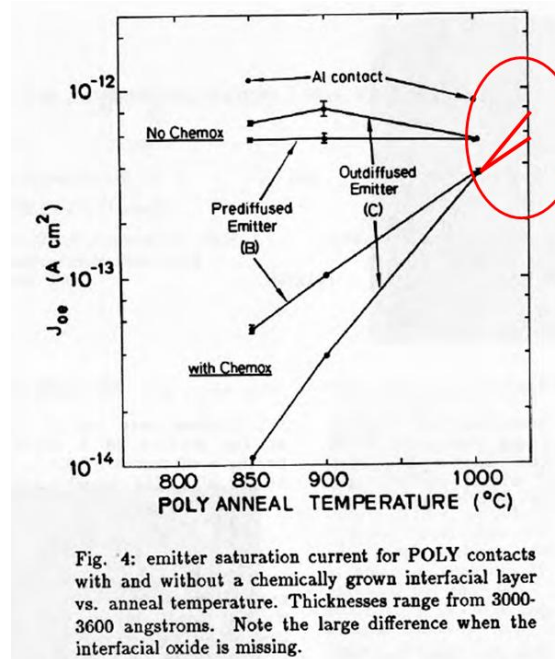


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

EX1008, Fig. 4 (annotated); EX2020, ¶220.

Specifically, Kwark explains that “Fig. 4 displays the resulting J_{oe} as a function of annealing temperature for emitter B.” *Id.*, 743. Figure 4 of Kwark is relevant because CSI relies on it to argue motivation for its proposed combinations of Froitzheim with Gan or, alternatively, with Kwark. *See e.g.*, Petition, 59.

Further, as shown below, if the emitter lines are extended (in red) into the temperature ranges disclosed as preferable in Froitzheim, all benefits arising from the use of Chemox are lost. EX2020, ¶221.



EX1008, Fig. 4 (annotated); EX2020, ¶221.

Therefore, given the rapid breakup of the interfacial oxide layer at temperatures above 850 $^{\circ}C$, as taught by Kwark, and the much higher temperatures taught as being preferable by Froitzheim, a POSITA would not have a reasonable expectation of success in the combination of Froitzheim and Kwark. EX2020, ¶¶222; *see also id.*, ¶199. A POSITA would also not have chosen to form the interfacial Chemox oxide layer and polysilicon layer disclosed by Kwark on the surface of the silicon substrate of Froitzheim, because Gan, the Gan Thesis, and Kwark teach poor results would happen at the high anneal temperatures required by Froitzheim. *Id.*, ¶222.

Further, as noted above Kwark proposes using Chemox. *See. e.g.*, EX1008, Fig. 4. Chemox is a very crude form of creating silicon dioxide and this may be

the reason Kwark failed to create a uniform oxide layer and experienced significant increases in J_o if processing temperatures exceeded 850°C. EX2020, ¶223.

Further, the Gan Thesis disparages the use of Chemox. EX2020, ¶224. The Gan Thesis explains “[a]s mentioned previously, a very low J_o can be obtained (see Figure 3.6) for the N-type polysilicon SIS emitter with a chemically grown interfacial oxide. However, the corresponding ρ_c of such a device can be as high as $4 \times 10^{-4} \Omega\text{-cm}^2$ at the doping concentration of $1 \times 10^{20} \text{ cm}^{-3}$, which is the typical doping concentration of the emitter. This is four times higher than the value mentioned in the previous chapter as our goal, and the potential drop across the polysilicon emitter would be **intolerable**.” EX2003, 58 (39 in original) (emphasis added). Therefore, a POSITA would not have had a reasonable expectation of success in using this Chemox layer, and for this reason would not have been motivated to combine the Chemox layer and polysilicon layer of Kwark with Froitzheim. EX2020, ¶224. Additionally, the Gan Thesis proves that the results obtained by Kwark are not reproducible in a consistent manner. EX2020, ¶225.

2. *A POSITA Would Not Have Been Motivated to Combine Froitzheim and Kwark*

For the reasons discussed in the section above, *i.e.*, a POSITA would not have a reasonable expectation of success in the Froitzheim and Kwark combination, a POSITA would have lacked motivation to combine the references. EX2020, ¶226.

Finally, a POSITA would not be motivated to combine Kwark with Froitzheim because the use of intentionally broken SiO₂ layers would be a significant cause of concern for long-term performance degradation. As noted above, the Gan Thesis points out, reproducibility using Chemox is very difficult. Moreover, like Gan, a POSITA would have understood the incompatibility in temperature ranges taught in Froitzheim and Kwark for driving in the dopants and, just as discussed above with regard to the Froitzheim/Gan combination, the POSITA would have concluded that to adopt the temperature taught in one reference would have precluded the benefits to be achieved by using the temperature taught in the other reference.. EX2020, ¶227.

B. The Teachings of Froitzheim and Kwark Regarding the Temperature Used to Drive In Dopants Are Incompatible

A POSITA would not have combined Froitzheim with Kwark because their conflicting annealing temperatures show their incompatibility as discussed in § IX.A.1. This analysis is similar to that discussed above with regard to the Froitzheim and Gan combination in § VIII.C.

C. The Proposed Froitzheim-Kwark Combination Would Not Have Met Limitations in Claim 12 of the '516 Patent

As discussed in section VIII.D.1, CSI fails to explain how a POSITA would have modified the alternative embodiment of Froitzheim with a different rear structure, or whether a POSITA would have been motivated to perform such

modifications. As discussed in section VIII.D.2, this alternative embodiment also fails to satisfy the limitation of claim 12. CSI does not cure its deficient arguments in the proposed Froitzheim-Kwark combination. Petition, 63 (incorporating arguments from the proposed Froitzheim-Gan combination on claim 12).

X. CLAIMS 9-12 OF THE '516 PATENT ARE PATENTABLE UNDER FROITZHEIM AND BORDEN (GROUND 5)

CSI proposed Froitzheim-Borden combination fails because it relies on an interfacial oxide layer, i.e., an oxide layer between the substrate and the emitter as required by claim 9, which Borden does not disclose. Instead, CSI cites to oxide layers provided in different locations for different purposes. CSI also fails to show motivation to combine Froitzheim with any of Borden's oxide layers, or that there would be a reasonable expectation of success. Further, the proposed combination does not meet limitations recited in the claims.

A. CSI Fails to Show Why a POSITA Would Have Been Motivation to Combine Froitzheim and Borden

The proposed Froitzheim-Borden combination uses polysilicon emitters, but Borden's purported benefits are not directed to polysilicon emitter cells, but to Heterojunction with Intrinsic Thin-layer (HIT) solar cells, which features amorphous silicon layers on both sides of a substrate. Petition, 65 (proposing a combination with polysilicon emitters); *id.*, 66 (citing EX1009, Abstract) (alleging

motivation to combine); *but see* EX1009, ¶4 (disclosing the structure of a “typical HIT type solar cell”). Borden’s Abstract, when read in full, makes this clear:

Benefits of the invention include that it provides a controlled interface for the HIT cell through insertion of a thin tunnel oxide. Moreover, the tunnel oxide prevents epitaxial growth of amorphous silicon, allowing it to remain amorphous for the optimum band structure. Still further, it provides a layer to protect the surface from plasma damage during deposition of the a-Si layer.

EX1009, Abstract (emphasis added). Amorphous silicon (also referenced as “a-Si layer” in Borden) is a feature of “[a] typical HIT type solar cell.” *Id.*, ¶4; *see also id.*, Fig. 1B. Borden also expressly distinguishes HIT cells from polysilicon emitter cells “[Polysilicon emitter solar cells] do not provide the heterojunction and its benefit of a higher cell voltage due to the higher bandgap of a-Si.” EX1009, ¶16. This teaching in Borden shows why a POSITA would not make the proposed combination. EX2023, 139:21-140:22.

The structure of Borden’s HIT cell is shown below in Fig. 2A.



FIG. 2A

EX1009, Fig. 2A.

This structure shows, from front to back, an n-type substrate (206), a tunnel oxide layer 228, and amorphous silicon layer 224, and then a layer of TCO or transparent conductive oxide 222. EX1009, [0018]; EX2023, 136:16-137:14.

Petitioner proposes using the disclosure of Borden to replace the amorphous silicon layers (224 and 226) and TCO 222 layer with a polysilicon layer. Petition, 65, citing EX1009, [0016]; EX2023, 138:9-139:20. Borden also proposes using a masking layer on the front and back of the cell, and then patterning the masking oxide. However, CSI's proposed combination does not use this masking layer. EX2023, 141:4-142:16. So, the complete proposed structure of CSI's combination is, from front to back, silicon substrate layer 206, silicon oxide layer 228, and a polysilicon layer. The amorphous silicon layers have been removed from the combination. EX2023:138:21-139:20.

According to CSI, a POSITA would be motivated to make this combination because the oxide layer “prevents epitaxial growth, allowing for optimum band structure” and “provides a layer to protect the surface from plasma damage.” Petition, 66, citing EX1009, Abstract, ¶8; EX1003, ¶199. However, when the amorphous silicon is removed, these benefits do not apply to the combination. EX2023, 144:6-17, 146:14-147:13.

In other words, the purported benefit of the thin tunnel oxide is solely related to amorphous silicon, and amorphous silicon is not present in the proposed Froitzheim-Borden combination. Thus, a POSITA would not have been motivated to insert Borden’s tunnel oxide layer (unclear whether this is CSI’s proposed “interfacial oxide layer”) on Froitzheim because Borden’s purported benefits would not have been applicable to the proposed combination. EX2020, ¶234.

B. The Proposed Froitzheim-Borden Combination Does Not Include a “second metal contact” with “silver formed over a layer of silicon dioxide” (Claim 12)

As discussed in section VIII.D.1, CSI fails to explain how a POSITA would have modified the alternative embodiment of Froitzheim with a different rear structure, or whether a POSITA would have been motivated to perform such modifications. As discussed in section VIII.D.2, this alternative embodiment also fails to satisfy the limitation of claim 12. CSI does not cure its deficient arguments

in the proposed Froitzheim-Borden combination. Petition, 67 (incorporating arguments from the proposed Froitzheim-Gan combination on claim 12).

XI. CONCLUSION

For the foregoing reasons, claims 9-12 in the '516 patent are patentable.

Respectfully submitted,

Date: April 8, 2025

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CERTIFICATE OF WORD COUNT

Pursuant to 37 C.F.R. § 42.24(d), I certify that this Patent Owner Response, exclusive of the table of contents, table of authorities, certificate of service, certificate of word count, and list of exhibits, includes 13,296 words. Pursuant to 37 C.F.R. § 42.24(d), Patent Owner relied on the word count feature of the word-processing system used to prepare this paper.

Dated: April 8, 2025

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CERTIFICATE OF SERVICE

I certify that the foregoing Patent Owner Response was served on
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